STATE OF CALIFORNIA
The Resources Agency

# Department of Water Resources

in cooperation with
Santa Clara Valley Water District

## BULLETIN No. 118-1

# EVALUATION OF GROUND WATER RESOURCES: SOUTH SAN FRANCISCO BAY

## Volume III: NORTHERN SANTA CLARA COUNTY AREA



DECEMBER 1975

CLAIRE T. DEDRICK
*Secretary for Resources*
The Resources Agency

EDMUND G. BROWN JR.
*Governor*
State of California

RONALD B. ROBIE
*Director*
Department of Water Resources

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save water
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## FOREWORD

The South San Francisco Bay Ground Water Basin, which includes portions of Alameda, San Mateo, and Santa Clara Counties, underlies the southern portion of San Francisco Bay and its gently sloping bayshore plains. The ground water basin has been divided into three subbasins: the Fremont study area, encompassing the Alameda Creek-Niles Cone area and reported on in Volumes I and II of Bulletin No. 118-1, published in 1968 and 1973, respectively; the San Mateo study area, which includes the western shore of the bay; and the North Santa Clara County area, which is the subject of this volume of Bulletin No. 118-1.

Ground water has played an important part in the development of the Santa Clara Valley area since the first settlers arrived in 1777. As water needs exceeded supplies, most of the surface water runoff was controlled by reservoirs and released for ground water recharge. By the year 1950, almost all of the valley's water needs were met by water pumped from the underlying ground water basin, which was operated in conjunction with surface water storage. This development sent water levels to an all-time low of over 150 feet (46 meters) below the ground surface.

Imported water supplies have been available to the area since 1950 from the City of San Francisco's Hetch Hetchy Aqueduct and since 1965 from the State Water Project's South Bay Aqueduct. During the period 1965-1970, the amount of ground water in storage has increased about 60,000 acre-feet (74 cubic hectometers) a year. The local agency is now reaching the upper limit of its imported water entitlement. Increasing use of water will reduce additions to ground water in storage, and by the 1980's will bring about increasing depletion of ground water in storage unless corrective measures are taken.

This report contains an evaluation of the geologic and hydrologic characteristics of the ground water reservoir and describes the mathematical model developed to simulate the ground water system.

Recommendations are made with regard to a new monitoring well network which will accurately define water levels with respect to the aquifer system. This, in turn, will allow a more accurate determination of changes in the amount of ground water in storage and increase the accuracy of the model.

The study was conducted in cooperation with the Santa Clara Valley Water District. Results of the study will be used by the cooperating agencies to evaluate alternative management plans using surface, ground, and waste waters and for evaluation of artificial recharge sites and pumping pattern changes.

Ronald B. Robie

Ronald B. Robie, Director
Department of Water Resources
The Resources Agency
State of California

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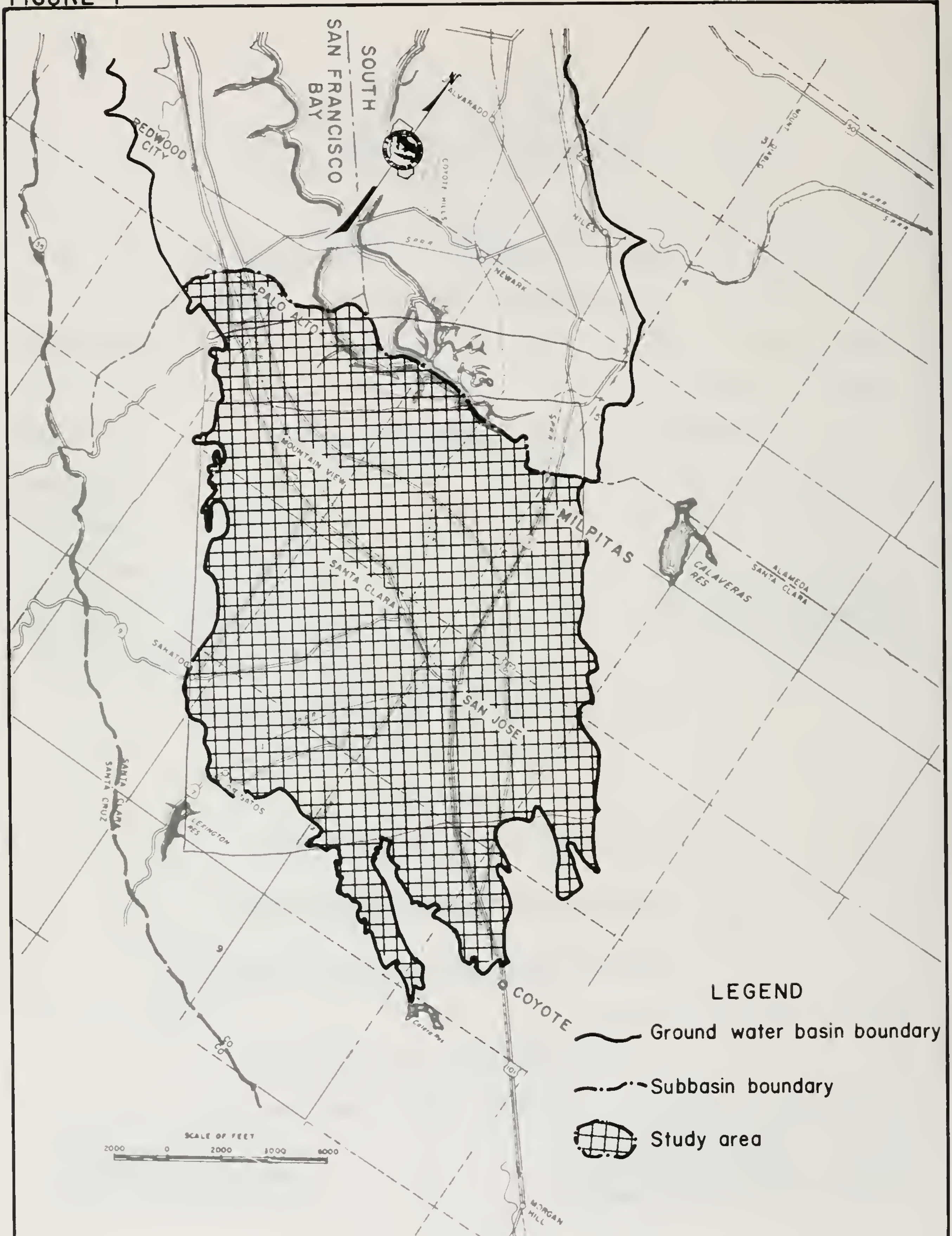
FIGURE 1




AREA OF INVESTIGATION

# CHAPTER I. INTRODUCTION

Since the settlement of Santa Clara County nearly 200 years ago, water has played an important role in the development and economy of the area. The development of an economy based on agriculture, particularly orcharding, and the start of urban development in the early part of this century was based almost exclusively on water pumped from the ground water body. In the years since 1950, local conservation projects and imported water supplies have been utilized in a race to keep up with continually increasing demands for water, and it is expected that even more water supplies will be required by 1980.

During periods when water demands exceeded supplies, the difference was met by overpumping of the ground water basin. When this adverse situation existed for more than just a few years, water levels fell to a point that permitted land subsidence to occur in the area surrounding South San Francisco Bay. Lands thus lowered by subsidence subsequently became subject to flooding from flood runoff and high tides and had to be protected by an extensive levee system.

Santa Clara County is a major water-consuming area, and it uses water supplies from both conservation reservoirs and ground water reservoirs. The effective use of water resources in the county is the concern of both state and local agencies because a part of the county's water supply is imported through the State Water Project and the Hetch Hetchy system of the City of San Francisco.

To obtain adequate information for the preparation of a series of water resource development plans, the State Department of Water Resources entered into an agreement with the Santa Clara Valley Water District to study the water resources of Santa Clara County. This bulletin presents in detail the geohydrologic conditions which affect the occurrence and movement of ground water in the northern part of Santa Clara County. The cooperative agreement is based on a 50-50 sharing of the costs of the study and has included full participation of the staffs of both agencies. A similar study is in progress covering the southern portion of the county. Additional studies of a wide range of management plans for both the north and south parts of the county will be made following the conclusion of the geohydrologic studies. Parallel studies by both agencies on possible use of waste water reclamation to extend the utility of present water supplies have been coordinated over the past two years and are continuing. Furthermore, a water quality management study is being conducted by the two agencies on a cooperative basis to provide information on cause-effect relationships and to form a basis for alternative water quality management plans.

The results of studies by the Department and the District are published so that information is available to local government representatives for consideration in adopting objectives, policies, and plans relative not only to water resource management, but also to other water-related resources.

## Area of Investigation

The area of investigation comprises the southern part of the South Bay ground water basin, as shown on Figure 1. The basin is bounded on the west by the Santa Cruz Mountains and on the east by the Diablo Range; these two ranges converge at Coyote Narrows to form the southern limit of the basin. The south part of the basin, the subject of this bulletin, includes northern Santa Clara County and adjacent portions of Alameda and San Mateo Counties.

The northern boundary of the immediate study area, just north of the Santa Clara County line as shown on Figure 1, was chosen for two reasons: (1) it represents the boundary of a manageable ground water unit, and (2) it delimits the depositional area of influence of Coyote Creek, Guadalupe River, and others which drain northerly into San Francisco Bay.

The southern boundary of North Santa Clara Valley, as used in this bulletin, differs from that used in State Water Resources Bulletin No. 7, "Santa Clara Valley Investigation". That bulletin identified the ground water divide near Morgan Hill as the southern boundary of the basin. In this bulletin, the constriction of the water-bearing materials at Coyote Narrows, one mile north of the community of Coyote, is used as the southern boundary of the ground water basin.

## Previous Investigations

Ground water has been and continues to be a major source of water for domestic, irrigation, and municipal uses in Santa Clara County. Interest in this subsurface source of water has resulted in the publication, since 1915, of seven significant reports covering all or parts of the present study area. These seven reports, and other geologic reports pertaining to the area, are listed in Appendix B, "Bibliography".

The drastic lowering of ground water levels prior to the 1920's, which resulted from heavy pumping draft, prompted Tibbetts and Kieffer (1921) to prepare the publication, "Report to Santa Clara Valley Water Conservation Committee on Santa Clara Valley Water Conservation Project". This report recommended the establishment of a water conservation district, the construction of dams and surface water conveyance facilities, and the extensive use of artificial recharge of ground water. The recommendations subsequently were adopted, and the facilities which were constructed allowed ground water levels to recover.

The Tibbetts and Kieffer report was followed by Clark (1924), who reported in some detail on the ground water conditions in Santa Clara Valley in U. S. Geological Survey Water-Supply Paper 519, "Ground Water in Santa Clara Valley, California". In this study, Clark included all of the present study area together with that portion of Santa Clara Valley south of Coyote Narrows.

In 1933, the California Division of Water Resources (predecessor to the Department of Water Resources), in response to a request by the newly established Santa Clara Valley Water Conservation District, published Bulletin 42, "Santa Clara Investigation". This bulletin described the historic decline of ground water levels, the amount of ground water depletion, and the quantity of replenishment from surface streams in the area.

The Division of Water Resources again studied that portion of Santa Clara Valley Ground Water Basin underlying Santa Clara County during the period from 1948 to 1954. In this latter investigation, considerable knowledge of the geologic conditions governing the movement of ground water was obtained in both North and South Santa Clara Valley, and the results were published in June 1955 as State Water Resources Board Bulletin 7, "Santa Clara Valley Investigation".

The history of land subsidence in the Santa Clara Valley was summarized by Poland and Green (1962) in U. S. Geological Survey Water-Supply Paper 1619-C, "Subsidence in the Santa Clara Valley - A Progress Report". This brief paper relates subsidence to geology and pumpage of ground water. Material presented in this paper was updated by Poland in 1971 with the publication of U. S. Geological Survey, San Francisco Bay Regional Environment and Resources Planning Study, Technical Report 2, "Land Subsidence in the Santa Clara Valley, Alameda, San Mateo, and Santa Clara Counties, California".

From 1962 to 1965, the Department conducted a geologic investigation of the South San Francisco Bay area and published its findings in August 1967 as Bulletin 118-1, "Evaluation of Ground Water Resources, South Bay, Appendix A: Geology".

The appendix describes in some detail the geology of the water-bearing sediments in the southern part of the San Francisco Bay area, which includes portions of Alameda, Santa Clara, and San Mateo Counties. Information presented is intended to support subsequent studies in the hydrology, water quality, and operational characteristics of the ground water basin. Included in the appendix is a brief discussion of the geologic history which relates the succession of significant geologic events in the area of investigation. Also included is a chapter on the geologic formations and their water-bearing characteristics. In this chapter are described the geologic materials that make up the basin, as well as the aquifers and confining beds that have been identified within them. The lithology of the more permeable Holocene and Pleistocene sediments is discussed. The older, underlying rocks, which generally are nonwater-bearing, also are briefly discussed. Structural features, such as faults, are discussed along with their relation to ground water movement.

The various exploratory phases of the investigation are described in the appendix, and there are brief sections on the collection and analysis of geologic and geophysical data, the drilling of test holes, and the installation of piezometers.

Finally, the physical and water-bearing characteristics of the various ground water areas, with their respective subareas, are discussed in detail. The discussion includes the location of boundaries and description of extent, thickness, lithology, and water-bearing character of aquifers and confining beds within each subarea.

## History of Water Use

Water has played a large and important role in the development of the valley portions of Santa Clara County since the first settlers arrived nearly 200 years ago. With the founding of Mission Santa Clara de Asis along the Guadalupe River by Franciscan padres in 1777, the valley was given its name. Later that same year, Pueblo de San Jose was founded nearby, making it the first civil settlement in California.

The valley has had four distinct periods of economic development and land use: cattle raising, grain farming, fruit production, and the present period of industry and urbanization. In the early part of the last century, cattle ranching was the principal activity in the valley. Following the gold rush, cattle ranching gave way to grain farming. In 1856, Pierre Pellier discovered that the climate and soil of Santa Clara Valley were ideal for raising prunes. By 1870, the prune became nationally popular, and valley farmers began intensive production of this and other deciduous fruits. Subsequently, the Santa Clara Valley became known as the dried fruit and the canning fruit center of the world. The acreages of fruit and nut trees increased tremendously, from 20,000 acres (8,100 hectares)* in the late 1880's to 110,000 acres (44,000 ha) in 1930. The water required to irrigate the orchards had a dramatic impact on local water supplies, and the draft upon the underground water resources of the valley was unprecedented. In 1934, water levels fell to 140 feet (43 meters) below the ground surface, in a valley which once had over 2,000 flowing artesian wells.

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*Metric unit equivalents are shown thus ( ). See Appendix C for equivalents.

The present municipal and industrial period began with the large influx of families and industry into the valley following World War II. The population surged to 291,000 in 1950 and by 1965 had more than tripled to over 900,000. This growth alone made water demands climb, but in addition, the per capita consumption increased 40 percent between 1950 and 1970, creating water needs that were phenomenal. By 1970, the water requirements of the north valley alone were nearly 250,000 acre-feet (308 cubic hectometers)*.

In 1950, most all of the valley's water requirements were met by water pumped from the underlying ground water basin. This stress on the basin sent water levels to an all-time low of over 150 feet (46 m) below the ground surface. To replenish the depleted ground water supply, the Santa Clara Valley Water District constructed eight conservation reservoirs with a combined capacity of over 150,000 acre-feet (185 $hm^3$). The reservoirs capture the runoff from winter rains and store the water until it can be released into streams and percolation ponds for recharge of the ground water basin.

The initial stages of the Hetch Hetchy Aqueduct were constructed by the City of San Francisco in 1934-35. However, it was not until 1952 that an 80 MGD (303,000 $m^3/d$) extension of the Hetch Hetchy System was completed across the northern Santa Clara Valley, where it now supplies water to Sunnyvale, Palo Alto, Mountain View and Milpitas. Hetch Hetchy imports have increased steadily, and were nearly 50,000 acre-feet (62 $hm^3$) in 1973.

When it became evident that the combination of Hetch Hetchy and local water supplies could not meet the water demands, plans were made to acquire additional water from sources outside the valley. The Santa Clara Valley Water District contracted with the State in 1961 to receive 88,000 acre-feet (109 $hm^3$) of water annually through the South Bay Aqueduct of the California Water Project through 1988. By 1994, the District is scheduled to receive a maximum of 100,000 acre-feet (123 $hm^3$) per year. Deliveries to the north valley began in July 1965 and have totaled 100,000 acre-feet (123 $hm^3$) a year. This quantity is composed of 88,000 acre-feet (109 $hm^3$) of contracted water and an additional 12,000 acre-feet (15 $hm^3$) of surplus water when available. Approximately half of this state water is treated for surface distribution. The remainder is used for artificial recharge of the ground water basin. Ground water levels have been recovering since the initiation of water importation through the South Bay Aqueduct.

Most of the increase in water demands are now supplied by treated imported water, and ground water production has remained relatively constant at approximately 150,000 acre-feet (185 $hm^3$) per year. Ground water supplied more than 96 percent of the water needs

* Cubic hectometer ($hm^3$) = 1 million cubic meters.

of Santa Clara County in 1950. In the south county area, all of the water needs are still met from ground water, while in the north county area, ground water now supplies only 60 percent of the total water demand.

The Penitencia Water Treatment Facility was completed in 1974 by the Santa Clara Valley Water District. This 20 MGD (76,000 $m^3/d$) plant treats South Bay Aqueduct water and, with the Rinconada Water Treatment Plant, completed in 1967, eventually will be treating nearly 70 percent of the total South Bay Aqueduct import.

Recent water demand projections indicate that demand will again equal or exceed supplies in the north part of Santa Clara County beginning in about 1978. The Santa Clara Valley Water District is presently considering alternative water supply sources to satisfy this additional need for 145,000 acre-feet (179 $hm^3$) of water. Emphasis is on efforts to secure this water from the San Felipe Division of the Federal Water Project, although the District is continuing to study local projects, waste water reclamation, and water-saving devices and practices.

## Current Investigation

The desired result of the geohydrologic phase of the study is a verified mathematical model of the ground water basin. Early in the study the need for further geologic work became apparent with regard to additional detail on aquifer systems previously identified as heterogeneous mixtures of aquifers and confining beds. The need for a refined geologic analysis was met by the development of a statistical approach to the examination of the large quantity of subsurface data available. The major additions to geologic knowledge made by this study are listed in Chapter III and include the results of a detailed analysis of the well drillers' logs to obtain a three-dimensional concept of the subsurface. The results are presented as (1) a contour map of the base of the water-bearing deposits, (2) locations of buried stream channel deposits, and (3) geologic cross sections of the ground water basin.

Chapter IV contains the hydrology in the form of an inventory, or accounting, of the amounts of recharge to and withdrawals from the ground water basin on an annual basis and explains the methods used to obtain numeric values. The simulation of the ground water system by a mathematical model, comparison of the inventory with change of ground water in storage, adjustment of the inventory and verification of the model are also reported. An analysis of historic data needs, as well as data requirements for present and future water resource management, is discussed in Chapter V, along with general criteria for development of water resource surveillance networks.

## CHAPTER II. CONCLUSIONS AND RECOMMENDATIONS

The conclusions of the geologic and hydrologic evaluations of the ground water system in north Santa Clara County are set forth below. Recommendations for the further refinement of these conclusions are shown at the end of this chapter.

### Conclusions of the Geologic Evaluation

The detailed study of the aquifer system in the north part of Santa Clara County identified and delineated a number of geologic features hitherto unknown. A discussion of these features appears in Chapter III of this bulletin; geologic conclusions, based on these features, are enumerated below:

1. Most streams draining the highland areas surrounding Santa Clara Valley have flowed across the valley floor at roughly their present locations for the past several million years.

2. Only a few streams have had major shifts in their channel locations, and these shifts have been due primarily to the geologic phenomenon called stream capture.

3. Former courses of streams occur today as buried channels composed of sand and gravel enclosed in finer-grained silt and clay.

4. Buried stream channels, which act as water-bearing conduits, are not continuous, but they have been separated into discrete segments due to post-depositional erosion and fault movement.

5. The periodic rise and fall of sea level has had a marked effect on the location and extent of the now-buried stream channels. During periods when the sea stood at a high level, beds of marine clay were deposited over older stream channel deposits. These now act as widespread confining beds to ground water contained in the underlying stream channel deposits.

6. The Santa Clara Valley apparently has been slowly subsiding during the past five to eight million years. This is suggested from the identification of stream channel deposits at a depth of 550 feet (168 meters) below present sea level.

7. There are a great many faults crossing the floor area of Santa Clara Valley; a number of these had not been previously identified. Although the direction and amount of displacement could not be determined, several of the faults appear to have displaced sediments within 50 feet (15 meters) of the present ground surface.

## Conclusions of the Hydrologic Evaluation

During the study period 1962-63 through 1969-70, the total increase in the amount of ground water in storage was about 330,000 acre-feet (407 $hm^3$), and the precipitation as measured at San Jose was eight percent above the long-time average. Also, during the study period, the total amount of water imported from the City of San Francisco Hetch Hetchy system and the State Water Project South Bay Aqueduct was about 540,000 acre-feet (666 $hm^3$). Without imported water supplies, the ground water basin would have suffered a net loss of ground water in storage of in excess of 210,000 acre-feet (259 $hm^3$). The basin also would be experiencing severe effects of continued land subsidence, and, in all probability, certain areas would have experienced water quality degradation from the upward movement of connate waters and the inland movement of salt water from the bay.

The levying of a ground water pump tax in 1965 has substantially reduced the amount of water being applied to acreage used for irrigated agriculture and orcharding.

Average recharge to the ground water basin during the 8-year study period was about 190,000 acre-feet (235 $hm^3$) per year. About 60 percent of the total replenishment to the ground water body is through the percolation of conserved and imported water in improved streambeds and percolation ponds.

In spite of its limitations, the mathematical model was found to be very useful as a tool to test the effectiveness of the various concealed faults on the movement of ground water. It is concluded that these concealed faults are not effective barriers in areas where major streams have existed throughout geologic time.

## Recommendations

It is recommended that the Santa Clara Valley Water District:

1. Complete verification of the ground water model developed in this study by:

    a. Redesigning its data collection system on the basis of the geologic and hydrologic information in this bulletin. A suggested water level measurement network is presented in Chapter V. The design of a compatible water quality surveillance network is proceeding under a separate cooperative program.

b. Testing the accuracy of the ground water model with the data collected during the first three to five years of operation of the redesign data collection system.

2. Use the model without waiting for verification to test the general response of the ground water system to a variety of alternative conjunctive operation plans.

3. Continue to cooperate with other local water agencies in conjunctive operations of the water resources of the area.

4. Take measures to assure that damaging overdraft does not recur by securing new sources of water as needed and obtaining necessary legal authority to prohibit damaging overdraft.

# CHAPTER III. GEOLOGIC FEATURES

The various geologic formations of the northern part of Santa Clara County may be divided into two basic groups for the purpose of ground water studies. Consolidated rocks, which range in age from Jurassic to late-Tertiary and in composition from marine sediments to volcanic rocks and serpentine, comprise the nonwater-bearing series. These rocks produce relatively small quantities of water from fractures and seams; the water may be of unpotable quality. By far the most important geologic materials in the Santa Clara Valley area are those of the water-bearing series. These range from Pleistocene to Holocene in age and consist of a thick sequence of valley-fill material ranging in composition from sand and gravel to silt and clay. Nearly all of the water wells in Santa Clara Valley derive their supply from the water-bearing series. All of the nonwater-bearing and water-bearing materials are briefly described below. A detailed description of these materials, as well as a geologic map depicting their surficial extent, appeared in Appendix A to this bulletin, which was published separately in August 1967.

## Nonwater-Bearing Series

Rocks of the nonwater-bearing series are exposed in the Santa Cruz and Diablo Mountains and also in the hills that rise above the alluvial plain of Santa Clara Valley. These rock types underlie all of the valley-fill materials at depths ranging from less than 100 feet (30 meters) to over 1,500 feet (460 meters). They mark the lower limit of ground water production in Santa Clara Valley and also define the bottom of the ground water basin. The geologic formations which comprise the nonwater-bearing rocks are composed of marine sediments and a variety of associated intrusive rocks; they range in age from Jurassic to late-Tertiary. The nonwater-bearing rocks all are consolidated and of low permeability. Ground water contained in them exists largely in fractures, joints, shear zones, and faults. These openings provide only minimal space for ground water storage and movement. Hence, these rocks usually provide only small quantities of water to wells. The quality of ground water in the nonwater-bearing rocks often is poor because most of the rocks are of marine origin and consequently may contain saline connate water.

## Water-Bearing Units

The sediments comprising the water-bearing formations are present as beds of unconsolidated to semiconsolidated clay, silt, sand, and gravel. The water-bearing materials fall into two principal groups: the older Santa Clara Formation and the younger valley alluvium.

## Santa Clara Formation

The Santa Clara Formation, which is of Plio-Pleistocene age, rests unconformably on the older rocks of the nonwater-bearing series. The formation was formed as a continental deposit that has been modified by subsequent folding and faulting; it now is exposed only along the west and east sides of Santa Clara Valley. The top of the Santa Clara Formation is encountered in the central portion of the valley at from depths of a few feet to over 200 feet (61 meters). Along the eastern side of the valley, the formation consists of obscurely bedded pebbly sandstone, siltstone, and clay. On the west side of the valley, exposures of the Santa Clara Formation show it to be composed of poorly sorted, irregularly bedded material ranging in grain size from silt to boulders.

Along the west side of the valley, the Santa Clara Formation dips eastward at from 10 to 65 degrees. Across the valley it appears to dip toward the west. Well data suggest that the permeability of the Santa Clara sediments increases from west to east, and the highest yielding wells tapping the Santa Clara Formation are on the eastern side of the valley. Beneath the central part of the valley, logs of deep wells show that the Santa Clara sediments decrease in grain size and in permeability with depth.

## Valley Alluvium

The valley alluvium is of Pleistocene to Holocene age and is the most important water-bearing unit in Santa Clara Valley. The permeability of the valley alluvium generally is high; all large production water wells draw their supplies from the valley alluvium. The alluvium is composed of gravel, sand, silt, and clay, all of which are generally unconsolidated. The sand and gravel deposits have the highest transmissivities and are the major water-producing units; conversely, the layers of silt and clay have low transmissivities and act as confining beds.

The valley alluvium has been deposited principally as a series of coalescing alluvial fans by the numerous streams which drain the adjacent highlands. The alluvium in the gently sloping central portion of the valley is composed of materials which were deposited by the many streams that meandered across the plain on their way to San Francisco Bay. The deposits which underlie the plain become progressively finer-grained toward the central part of the valley. Here, there is a series of blue clay layers that become increasingly thicker toward San Francisco Bay. The blue clay is believed to be of marine origin and was deposited as bay mud during interglacial periods when sea level stood at a higher elevation than at present.

## Base of Water-Bearing Deposits

Previous geologic work, published in Appendix A, identified the approximate base of the water-bearing deposits. Because the data presented in Appendix A had a contour interval of 500 feet (150 meters) (see Appendix A, Plate 4), a better definition of the base of the water-bearing deposits was required for the preparation of the mathematical model of the basin. Figure 2 in this bulletin presents a reevaluation of the data used in Appendix A, as well as an augmentation of additional data. The contour interval on Figure 2 is 100 feet (30 meters), which is of adequate detail to be used in the mathematical model. The base of the water-bearing materials could not be defined for the central and northern parts of the valley due to a lack of adequate well data. All wells used which penetrated nonwater-bearing rock are indicated on the figure.

## Subsurface Deposition

The geologic information summarized in Appendix A was found to be of insufficient detail to define the aquifer system in Santa Clara Valley to the level required for the mathematical model. To tattain this level it was necessary to identify and plot the courses of the now-buried ancient stream channels in the valley. These channels act as conduits for the transmission of ground water from areas of recharge to areas of discharge. In a sense, the channels are an intricate network of pipes underlying the valley floor.

In order to identify these channels, it was first necessary to catalog all of the water wells in the north valley area for which data are available. The data were placed in a computer file and listings obtained, tabulated numerically by well location and alphabetically by well owner, which showed the well location number, owner, well depth, year drilled, well driller, and types of data on file. In all, 3,273 wells were tabulated. Most wells were found to be not over 800 feet (244 meters) in depth; the deepest well in the valley is San Jose Water Works Well No. 2 at the 17th Street Station. This well (No. 7S/1E-9D12) was drilled to a depth of 1,535 feet (468 meters) in 1910.

## Computer Assisted Subsurface Geologic Evaluation

One of the principal tasks in the Santa Clara Valley area was the identification of the buried channel network within the ground water basin. This was accomplished through the application of a computer-assisted program, called the GEOLOG program, which presented subsurface data from well logs in a three-dimensional display. What is found in the subsurface is the product of a series of events that include deposition, folding, faulting, and erosion. This has resulted in the valley alluvium being composed of a sequence of meandering permeable stream channel deposits separated by less permeable silts and clays. Hence, instead of widespread aquifers separated by confining beds, there were found to be numerous tabular bodies composed of sand and gravel enclosed by silt and clay.

The main data input to the GEOLOG program were the logs of the deepest wells in each quarter-quarter section. Using this well spacing allowed for a theoretical maximum number of 4,256 data points throughout the valley. In analyzing the selected logs, it was found that the "calls" that various drillers used differed for the same material. It also was found that drillers' "calls" can be grouped, and thus a statistical analysis could be made based on these "calls". This same approach was used by Davis and others (1959), who grouped the drillers' "calls" by specific yield values in their study of the San Joaquin Valley. This grouping of "calls", modified for the Santa Clara Valley area, is presented on Table 1.

Using the groupings of drillers' "calls" shown on Table 1, the Equivalent Specific Yield value is assigned to each interval for each selected well log. Equivalent Specific Yield, or ESY, is defined as being a property of the geologic materials numerically equal to the Specific Yield but without the connotation of either the quantity of ground water contained therein or the degree of confinement. Data are then fed into the computer for all selected wells in the ground water basin. The computer, utilizing the GEOLOG program, averages the ESY values for each depth increment and prints maps of the basin for the various depth increments. The basic type of output are maps showing numeric values at each well location. These values are that of the average ESY for the particular depth increment.

A more useful printout is the symbolic type, the symbols for which are shown below:

| Group | ESY Value | GEOLOG Symbol |
|---|---|---|
| Rock | 0 | * |
| Clay | 3 to 7 | . |
| Clay-Sand | 8 to 12 | - |
| Sand-Clay | 13 to 17 | + |
| Gravel-Sand | 18 to 25 | 0 |

From this it can be seen that most clays, hardpans, and the like will appear as a dot, and the coarse-grained aquifer material will appear as a zero. Division of the materials into these basic symbols simplifies the statistical analysis as well as equalizes differences in drillers' "calls" caused by differing drillers identifying the same material by different names.

For development of geologic cross-sections, the data for each well log is processed by computer to obtain a symbolic representation of the well log based on a series of layers of uniform depth. For example, if the information is based on layers of a ten-foot (3-meter) thickness, the result is a symbolic log having a scale of one inch (2.5 cm) equals 100 feet (30 meters). The output from the computer includes the well number, ground elevation, and the elevation of the top of the log. The geologic cross-section is the combination of a ground-surface profile and symbolic logs. The cross-section is used in developing correlations of coarse-grained materials between symbolic logs.

To assist in analysis of the fine materials, another related computer program was developed. In the Reduced Clay Program, the color of the clayey materials shown on the well logs is coded in the same manner as the ESY values. In this case, reduced clays, which are those reported on the logs as being blue, gray, or green, were coded with a 99. Oxidized clays, those reported as yellow, tan, brown, or red, were coded with a zero. The computer then provided a weighted average for these two values over each ten-foot (3-meter) interval. From this, areas of marine clays (that is, reduced clays) could be differentiated from the areas of terrestrial clays (the oxidized clays).

The final cross sections, shown on Figure 3 (at end of chapter), included interpretations of both the symbolic well logs and the reduced clay logs. Shown are zones of coarse-grained aquifer materials (the stippled pattern), zones of oxidized clay (blank areas), and zones of reduced marine clays (line pattern). Individual wells are not identified due to restrictions in the California Water Code prohibiting the publication of confidential well data.

The second, and perhaps more important, use of the GEOLOG Program is the preparation of maps of the subsurface at differing elevations. In this application, the computer output is an areal map of each township for each ten-foot (3-meter) depth interval. For geologic interpretation, all townships for a given elevation are spliced together and reproduced on transparent media. The transparencies then are stacked for viewing. In Santa Clara Valley, maps were prepared for ten-foot (3-meter) intervals from a top level of +290 feet (+88 meters) to a bottom level of -550 feet (-168 meters). Preparation of maps below this latter elevation was not possible because the number of data points drops off markedly. However, it can be assumed that zones of channel material exist to an elevation of at least -1,440 feet (-439 meters) based on the log of the deepest well in the valley.

Because of the natural slope of the stream channel deposits, each channel theoretically will describe an ellipse as it passes through each horizontal level. Thus, when a sequence of levels is viewed from above, a stream channel can be seen meandering downward through the various levels. This was found to be the case for the various buried channels of Coyote Creek, Guadalupe River, Stevens Creek, and other major streams. In viewing these levels, it was found that some stream channel deposits appeared to end abruptly. Some of these discontinuities could be attributed to erosional features. However, it was noted that a number of these discontinuities appeared to fall in line. Furthermore, several alignments appeared to be extensions of mapped fault zones. Thus, a technique was developed where fault lines could be inferred. Figure 4 shows a number of fault traces which were identified through the use of the GEOLOG program. Figure 5 shows maps of the buried stream channel deposits which also were identified by the GEOLOG program. These maps include a number of elevation intervals from +100 to +50 feet (+30 to +15 meters) to -500 to -550 feet (-152 to -168 meters).

Utilization of a computer-assisted geologic analysis has greatly increased the ability to adequately analyze the aquifer system in a ground water basin. Heretofore it was necessary to employ geologic expertise in the construction of endless cross sections.

Even then, a horizontal display of the meandering stream channels was lacking. Now, through the use of these new techniques, it has become possible to undertake the detailed analysis of a ground water system at almost any level of detail, the only constraint being the level of adequate well log data.

Other ramifications of the GEOLOG method include the utilization of the numeric data for the estimation of ground water storage capacity, the assignment of transmissivity values, and a number of other geohydrologic parameters necessary for the efficient operation of a mathematical model of a ground water basin.

## Faults

Geologic interpretation, using the GEOLOG program, identified many fault traces crossing Santa Clara Valley which hitherto had not been known. The faults appeared as discontinuities on the various computer printout maps of stream channels. Proof of the existence of a number of these faults was borne out in several ways. Some lines of discontinuities appeared as extensions of fault zones previously mapped in upland areas; this was the case of the Cascade Fault (see Figure 4) which had been mapped previously in the Santa Teresa Hills and is shown as the unidentified fault separating Jurassic from Cretaceous rocks on Plate 3 of Appendix A to this bulletin. The Santa Clara Fault, which also has been called the Stanford Fault, is shown as an unidentified fault on Plate 3 of Appendix A. This fault, which was inferred from geophysical data and extends from Redwood City southward to Los Altos on Plate 3, Appendix A, has been further extended on Figure 4 of this bulletin until it now is considered a major structural feature of Santa Clara Valley.

On the east side of Santa Clara Valley, the Hayward Fault previously was mapped only as far south as about Penitencia Creek. Work on the subsurface geology for this bulletin suggests that the fault does not terminate there, but rather it divides into several branches. The existence of one of these branches was further suggested by geophysical studies performed by private consultants for a foundation study for a pipeline.

Of importance to ground water movement and the construction and operation of the mathematical model was the identification of the uppermost level at which the various faults disrupt the water-bearing materials. Although this could not be precisely determined, many of the faults appear to offset buried stream channels as close as 50 feet (15 meters) below ground surface. Thus, much of the Santa Clara Valley area appears to be compartmentized with respect to ground water movement.

## Storage Capacity and Transmissivity

The gross storage capacity of Santa Clara Valley ground water basin has been calculated as the theoretical volume of water that is capable of being contained between the base of the water-bearing materials and ten feet (3 meters) below ground surface; it is based on specific yield values shown in Table 1.

The portion of the gross storage capacity shown on Table 2 that can be considered as usable storage capacity has not been determined, but is limited by operational controls to prevent land subsidence and avoid excessive pumping lifts and adverse water quality effects.

Transmissivity values were estimated using a relationship between specific yield and permeability. This relationship was derived for the mathematical model of Livermore Valley and is described in detail in Department of Water Resources Bulletin No. 118-2, "Livermore and Sunol Valleys: Evaluation of Ground Water Resources", March 1974. The values for permeability which were used in the current study are presented on Table 3.

The values describe a curve, and equations describing this curve were derived for input to the computer. That part of the curve for specific yield values from 3 to 10 is described by the following equation:

$$\Delta T = \Delta D \cdot 10^{\,3.5319 \quad \frac{7.16288}{|sy|^{-0.84}}}$$

and that part for specific yield values greater than 10 is described by the equation:

$$\Delta T = \Delta D\ (100|sy|-500),$$

where $\Delta T$ = incremental transmissivity in gallons per day per foot[1/],
$\Delta D$ = incremental depth, in feet, and
$|sy|$ = absolute value of specific yield for given interval

1/ Gpd/ft = 0.0124 $m^2$/d.

In addition to the above, a computer program also was written to accept specific yield data which had been coded for the GEOLOG program. Output of this latter program was the summation of the transmissivity values for each node, from bottom to top. These were directional values of transmissivity for flows along the previously identified depositional channels. For use in the mathematical model, the values were modified to apply to each nodal branch.

TABLE 1

SPECIFIC YIELD VALUES FOR DRILLERS CALLS

| Type of Material and Specific Yield | Drillers Calls | | |
|---|---|---|---|
| Crystalline Bedrock | Granite | Hard Rock | |
| Specific Yield = | Lava | Rock | |
| 00 Percent | | | |
| Clay and Shale | Adobe | Granite Clay | Shale |
| Specific Yield = | Boulders in Clay | Hard Clay | Shaley Clay |
| 01 Percent | Cemented Clay | Hard Pan | Shell Rock |
| | Clay | Hard Sandy Shale | Silty Clay Loam |
| | Clayey Loam | Hard Shell | Soapstone |
| | Decomposed Shale | Muck | Smearey Clay |
| | | Mud | Sticky Clay |
| Clayey Sand and Silt | Chalk Rock | Peat | Sandy Clay |
| Specific Yield = | Clay and Gravel | Peat and Sand | Sandy Silt |
| 05 Percent | Clayey Sand | Pumice Stone | Sediment |
| | Clayey Silt | Rotten Conglomerate | Shaley Gravel |
| | Conglomerate | Rotten Granite | Silt |
| | Decomposed Granite | Sand and Clay | Silty Clay |
| | Gravelly Clay | Sand and Silt | Silty Loam |
| | Lava Clay | Sand Rock | Silty Sand |
| | Loam | Sandstone | Soil |
| Cemented or Tight Sand or Gravel | Black Sand | Cemented Sand and Gravel | Hard Sand |
| Specific Yield = | Blue Sand | Dead Gravel | Heavy Rocks |
| 10 Percent | Caliche | Dead Sand | Lava Sand |
| | Cemented Boulders | Dirty Pack Sand | Soft Sandstone |
| | Cemented Gravel | Hard Gravel | Tight Boulders |
| | Cemented Sand | | Tight Coarse Gravel |
| | | | Tight Sand |
| Gravel and Boulders | Cobbles and Gravel | Gravel and Boulders | Rocks |
| Specific Yield = | Coarse Gravel | Heaving Gravel | Sand & Gravel, Silty |
| 15 Percent | Boulders | Heavy Gravel | Tight Fine Gravel |
| | Broken Rocks | Large Gravel | Tight Medium Gravel |
| | | Muddy Sand | |
| Fine Sand | Fine Sand | Quicksand | Sand, Gravel, and Boulders |
| Specific Yield = | | | |
| 15 Percent | | | |
| Sand and Gravel | Dry Gravel | Gravelly | Sand and Gravel |
| Specific Yield = | Loose Gravel | Gravelly Sand | Sand |
| 20 Percent | | Medium Gravel | Water Gravel |
| Coarse Sand and Fine Gravel | Coarse Sand | Fine Gravel | Medium Sand |
| Specific Yield = | | | Sand and Pea Gravel |
| 25 Percent | | | |

Modified after Davis, and others (1959).

TABLE 2

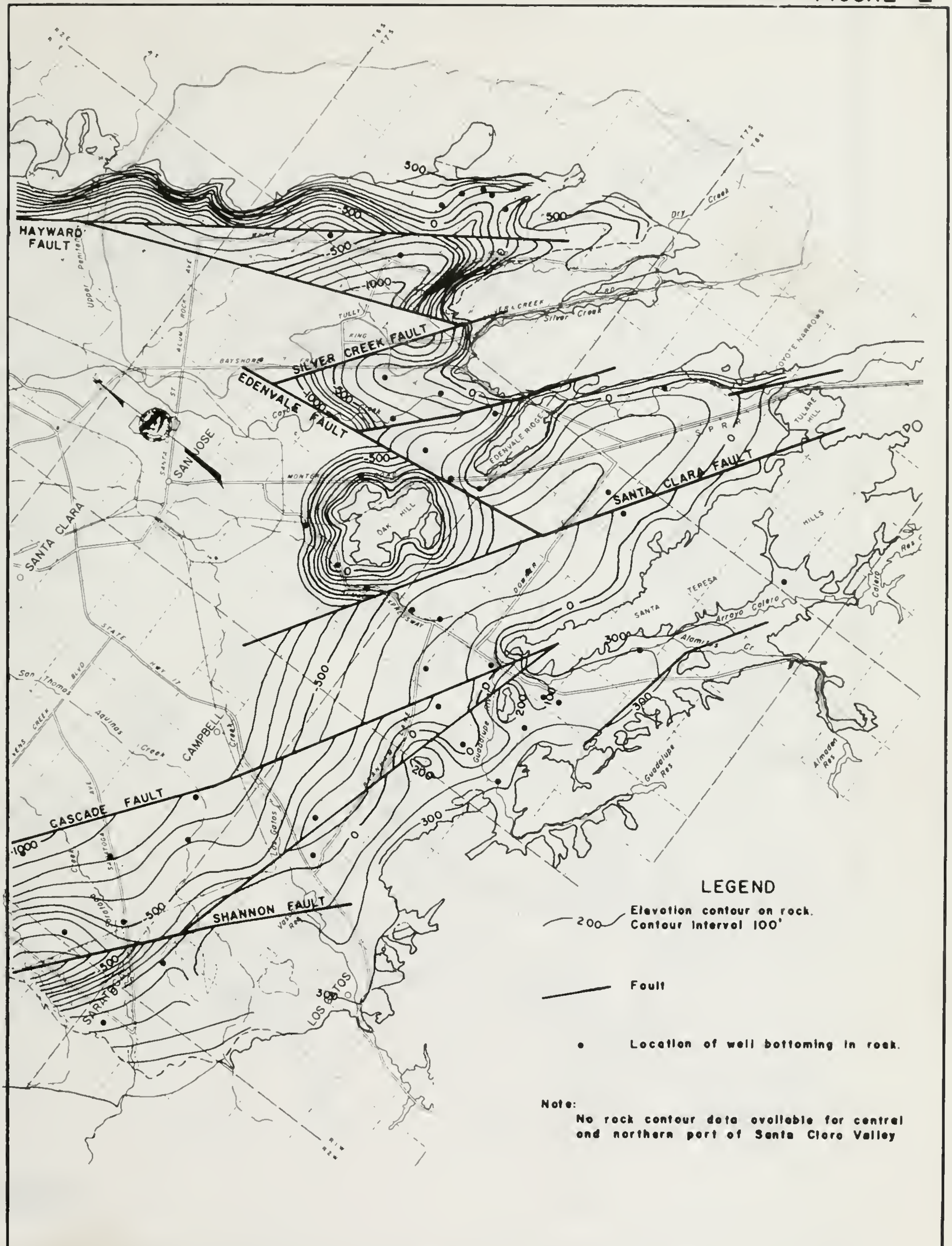
GROSS GROUND WATER STORAGE CAPACITY

| Depth below Ground Surface (feet) | | Gross Storage Capacity | Depth below Ground Surface (meters) | | Gross Storage Capacity |
|---|---|---|---|---|---|
| From | To | (acre-feet) | From | To | (cubic hectometers) |
| 10 | 110 | 1,220,000 | *3* | *34* | *1,504* |
| 10 | 210 | 2,267,000 | *3* | *64* | *2,795* |
| 10 | 310 | 3,255,000 | *3* | *94* | *4,013* |
| 10 | 410 | 4,195,000 | *3* | *125* | *5,172* |
| 10 | 510 | 5,020,000 | *3* | *155* | *6,190* |
| 10 | 610 | 5,695,000 | *3* | *186* | *7,022* |
| 10 | 710 | 6,331,000 | *3* | *216* | *7,806* |
| 10 | 810 | 6,825,000 | *3* | *247* | *8,415* |
| 10 | 910 | 7,088,000 | *3* | *277* | *8,740* |
| 10 | 1,010 | 7,257,000 | *3* | *308* | *8,948* |

TABLE 3

PERMEABILITY

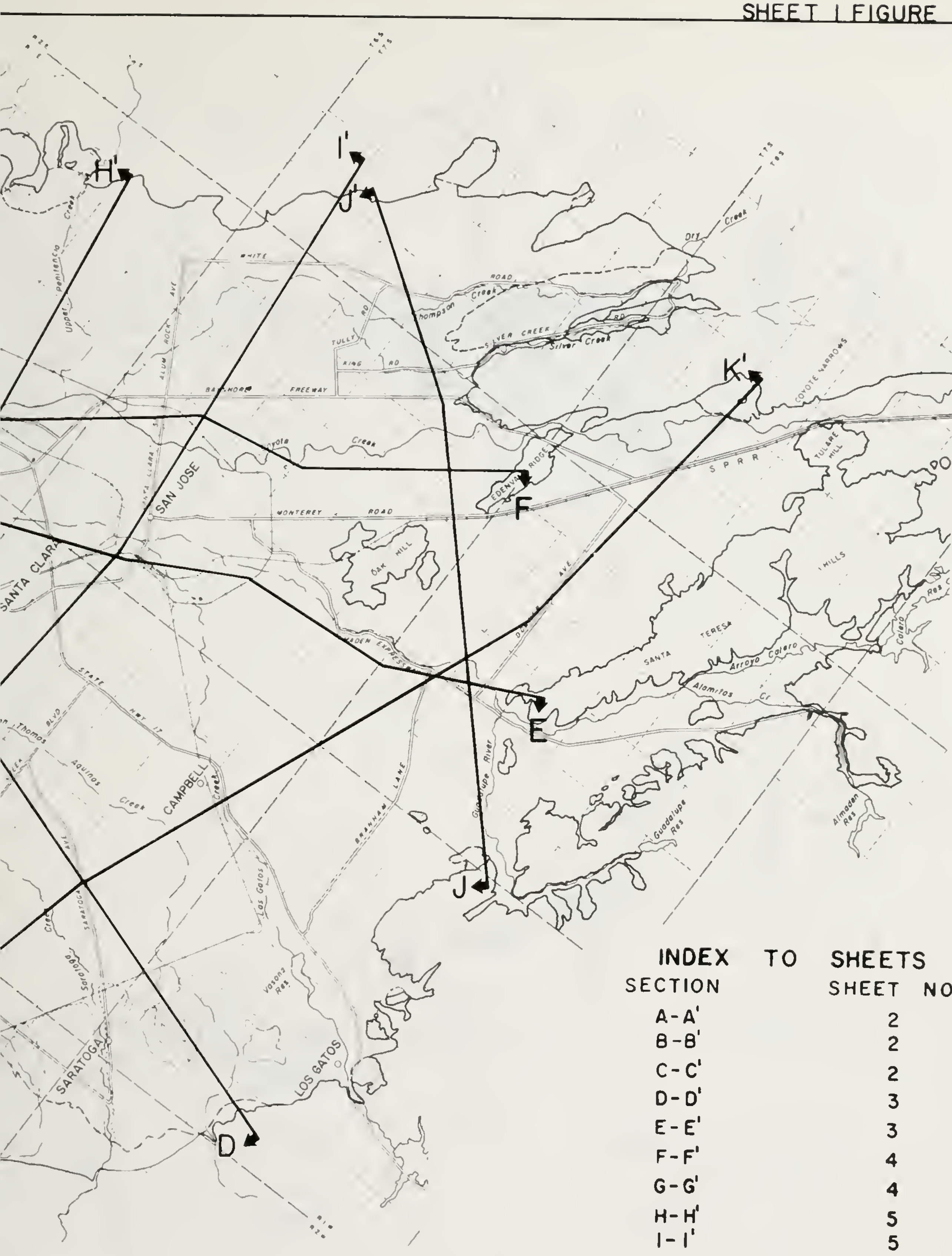
| Specific Yield | Permeability | |
|---|---|---|
| (percent) | (gal/day/ft$^2$) | (darcys) |
| 3 | 1 | *0.055* |
| 5 | 30 | *1.65* |
| 10 | 400 | *22.0* |
| 15 | 800 | *44.0* |
| 20 | 1,200 | *66.0* |
| 25 | 1,500 | *82.5* |




ELEVATION CONTOURS ON UPPER SURFACE
OF NONWATER-BEARING ROCK


## INDEX

# GEOLOGIC SECTIONS

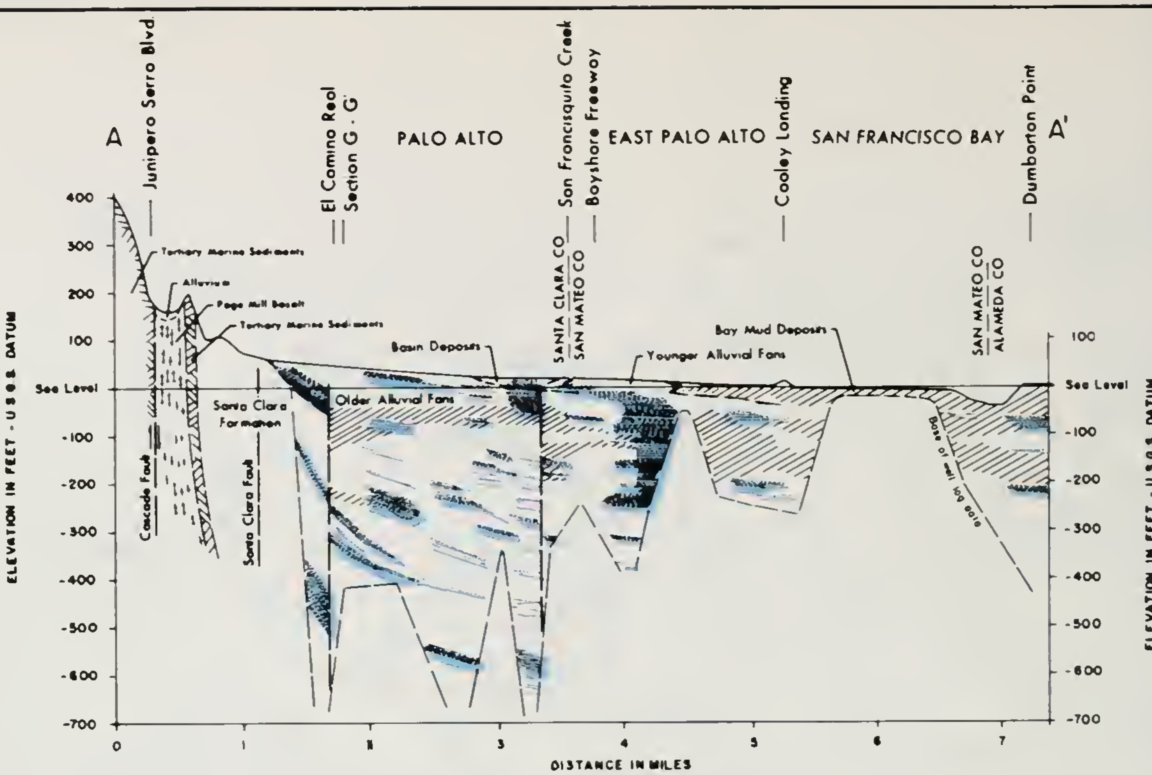


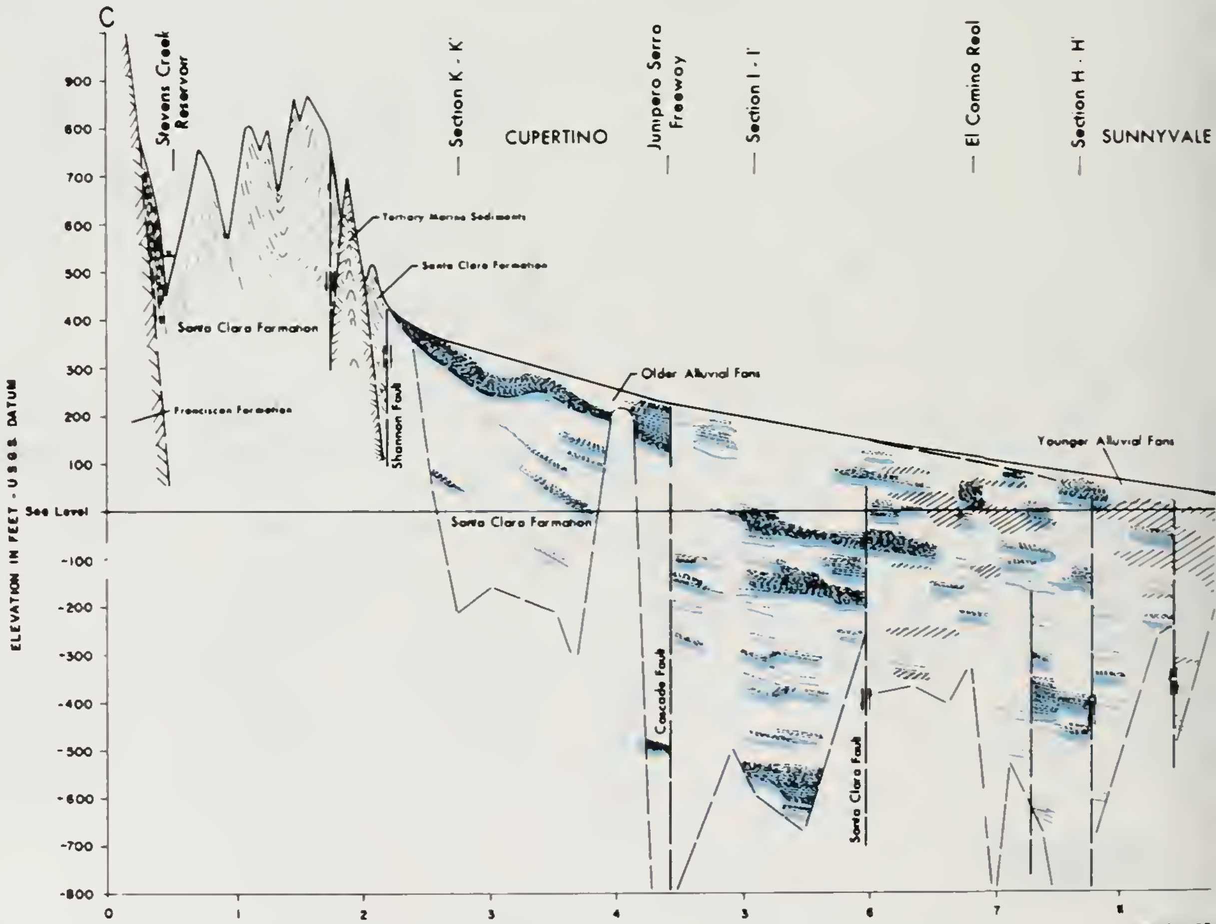

## INDEX TO SHEETS

| SECTION | SHEET NO. |
|---|---|
| A-A' | 2 |
| B-B' | 2 |
| C-C' | 2 |
| D-D' | 3 |
| E-E' | 3 |
| F-F' | 4 |
| G-G' | 4 |
| H-H' | 5 |
| I-I' | 5 |
| J-J' | 6 |
| K-K' | 6 |

SHEET

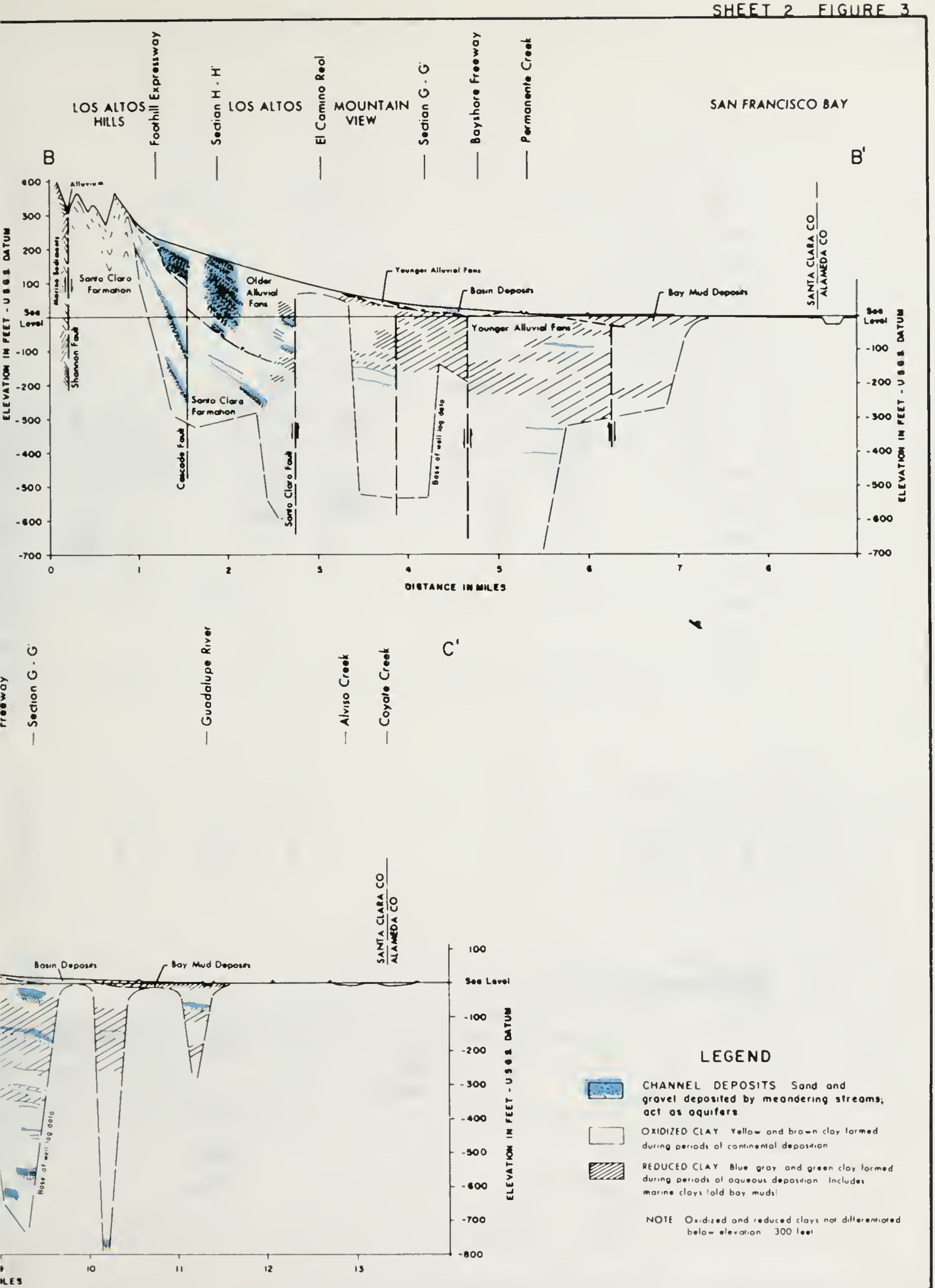
SANTA CLARA VALLEY




# GEOLOGIC SECTIONS

See Sheet I for location of section

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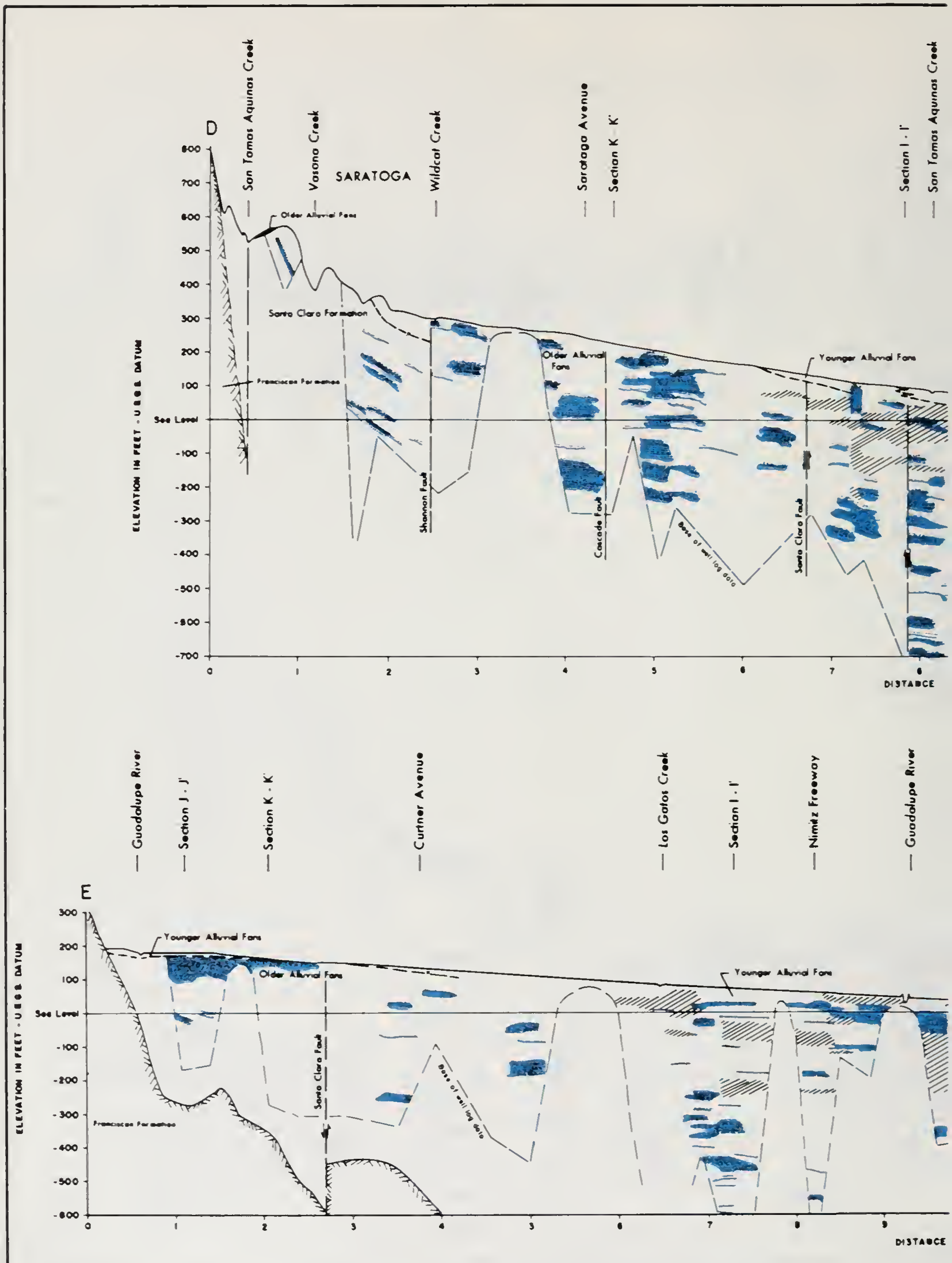
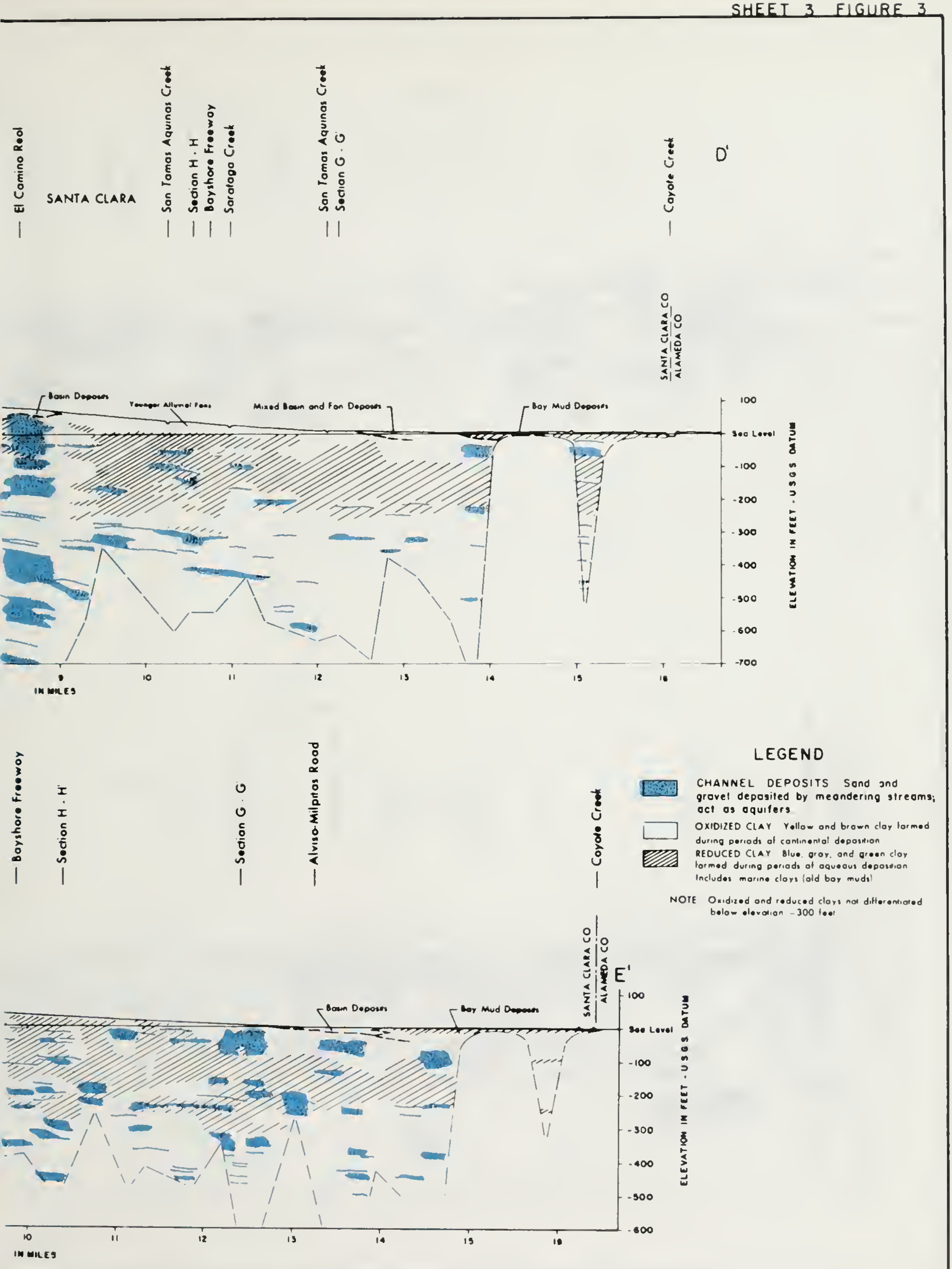



# GEOLOGIC SECTIONS

See Sheet 1 for location of section

SHEET 3 FIGURE 3

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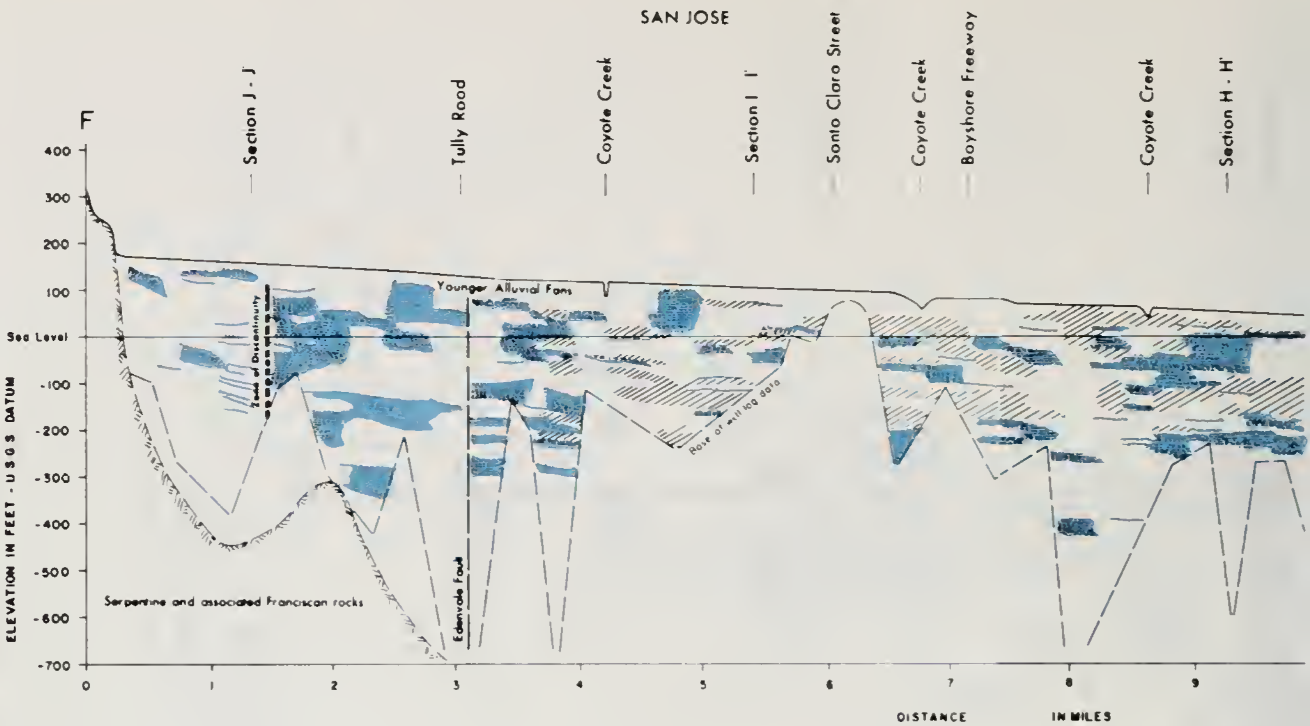


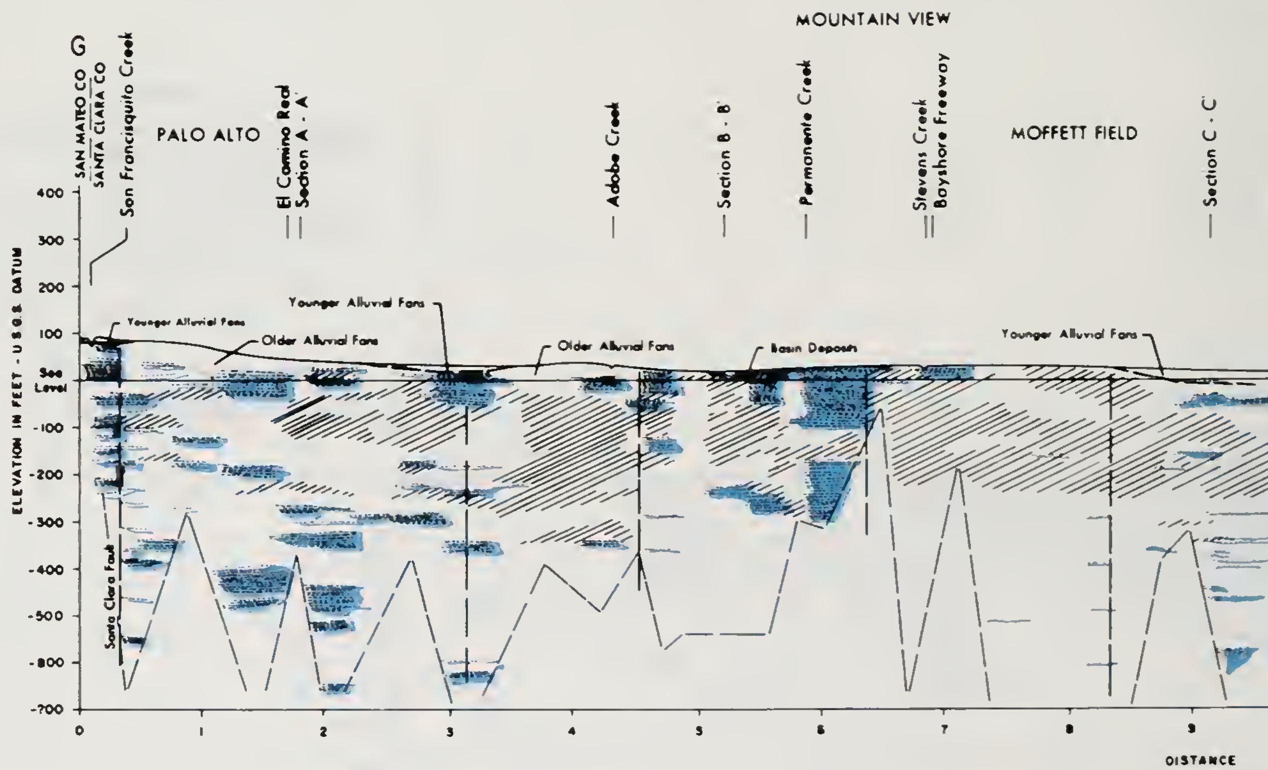


# GEOLOGIC SECTIONS

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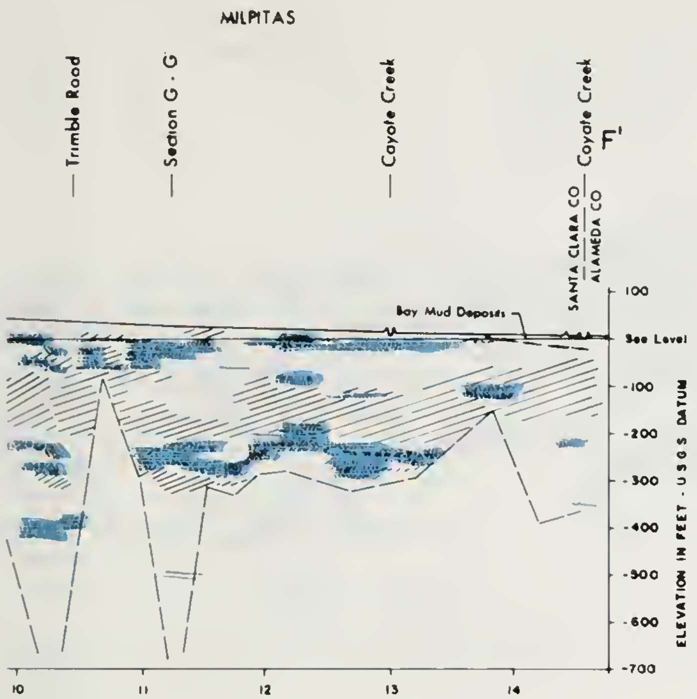


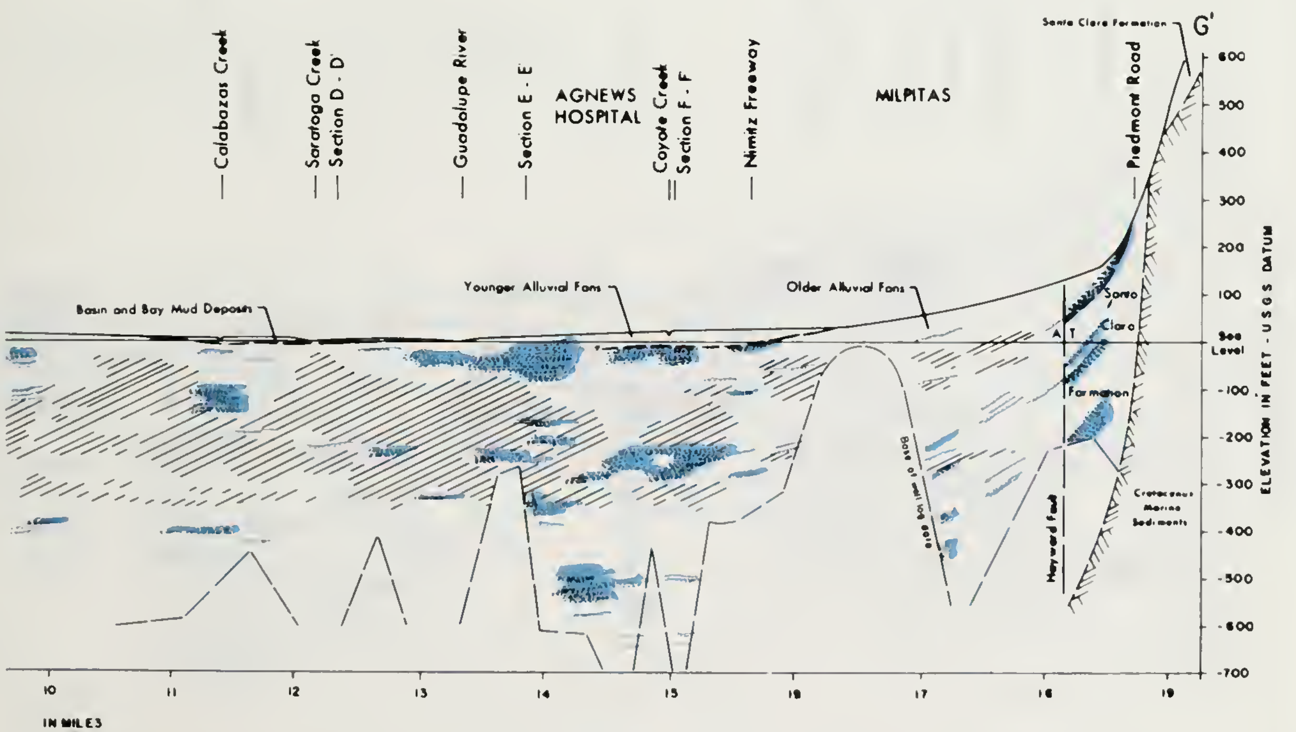

## LEGEND

CHANNEL DEPOSITS Sand and gravel deposited by meandering streams; act as aquifers.

OXIDIZED CLAY Yellow and brown clay formed during periods of continental deposition

REDUCED CLAY Blue gray and green clay formed during periods of aqueous deposition Includes marine clays (old bay muds)

NOTE Oxidized and reduced clays not differentiated below elevation −300 feet

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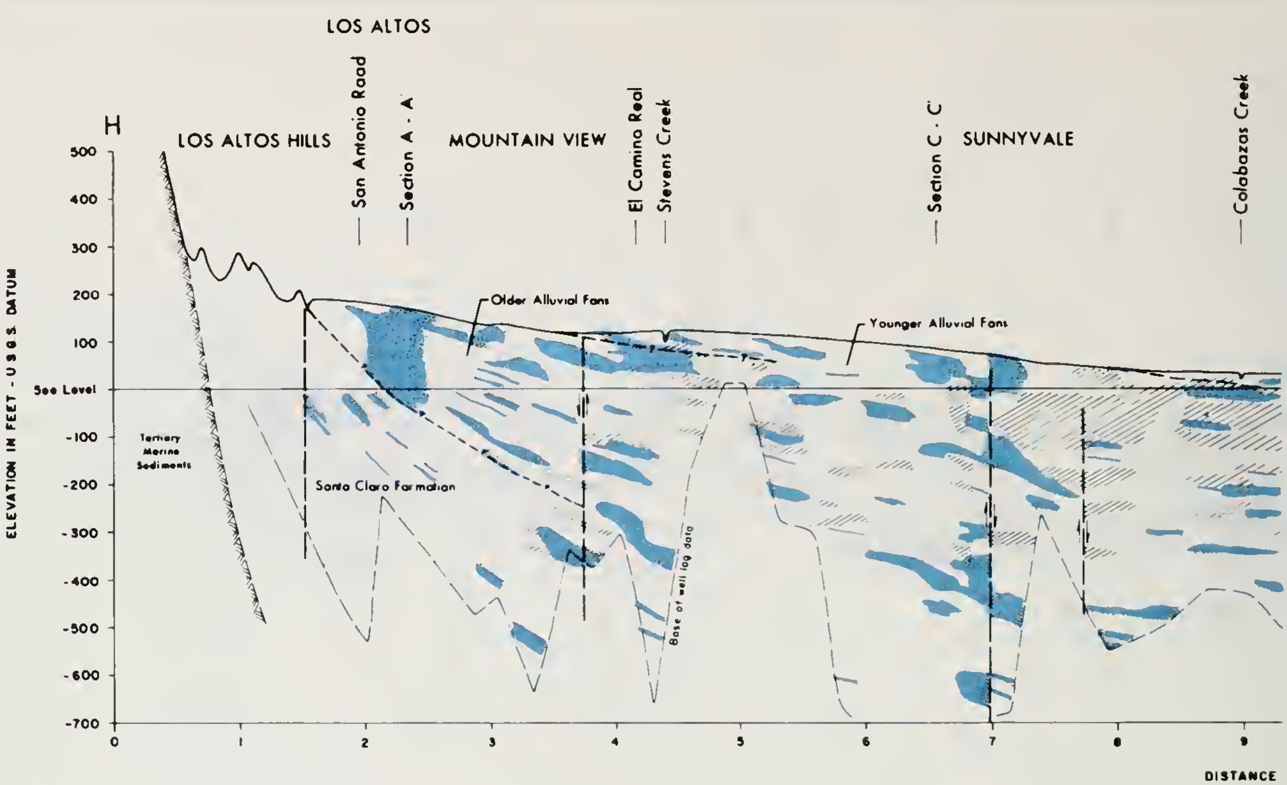


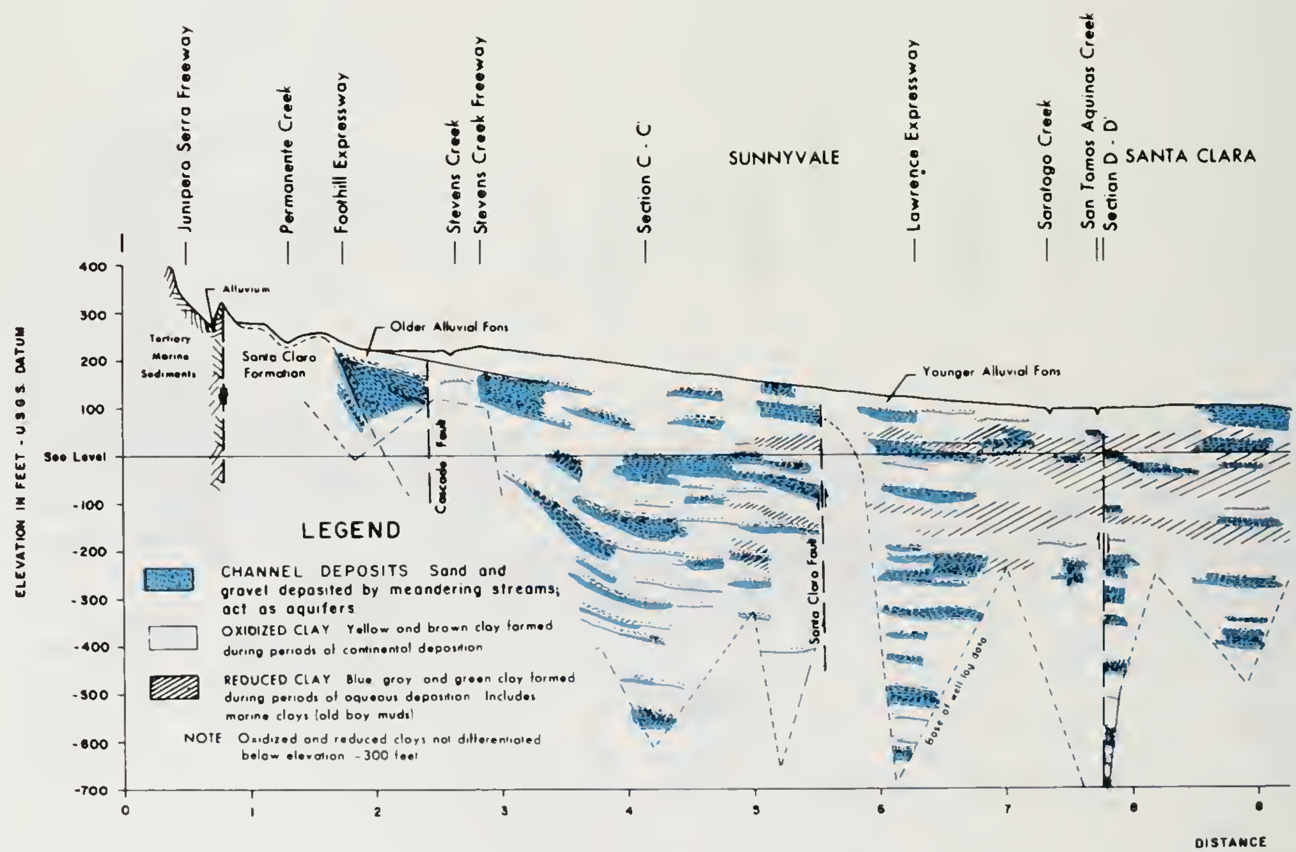


GEOLOGIC SECTIONS

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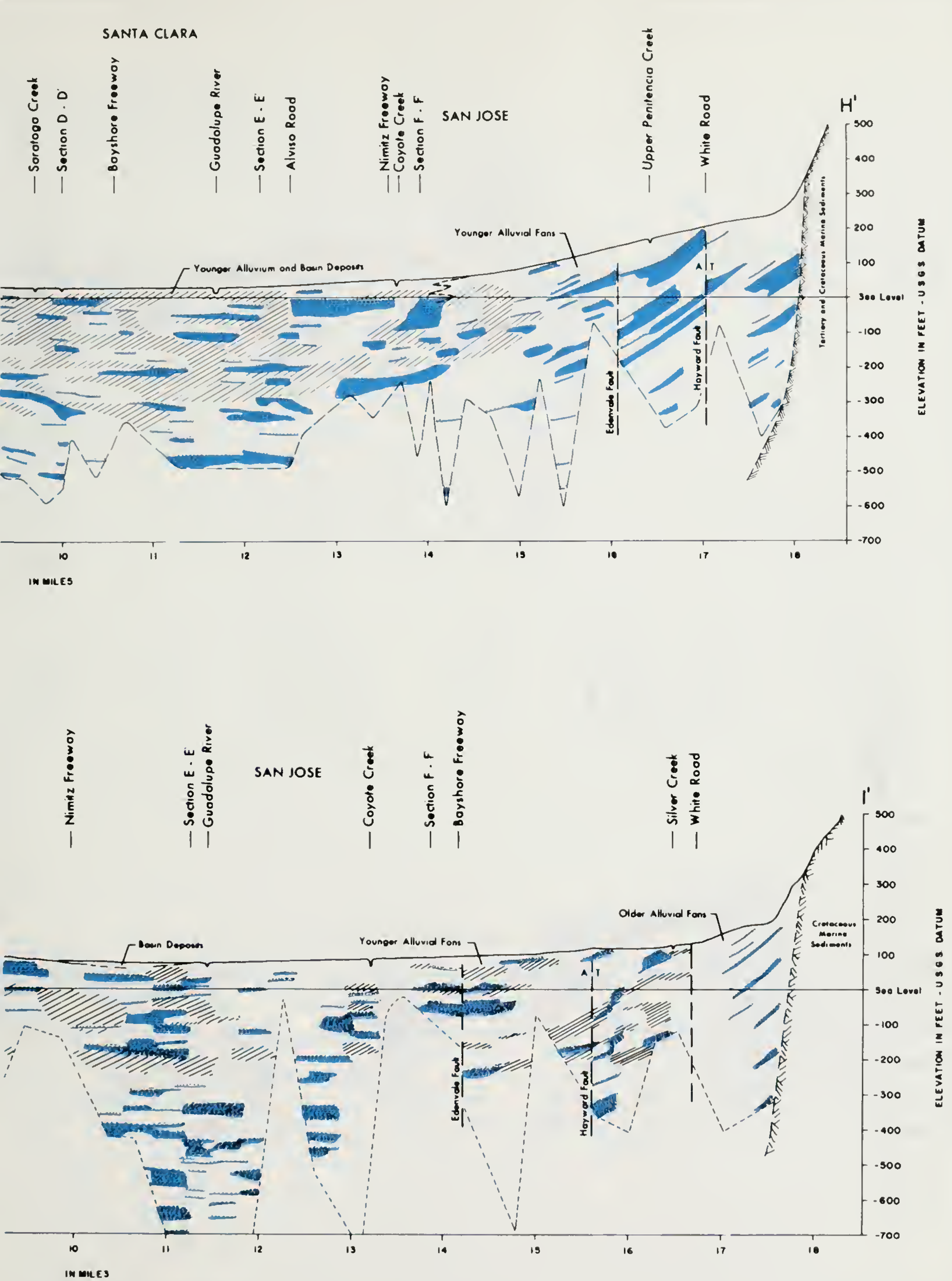


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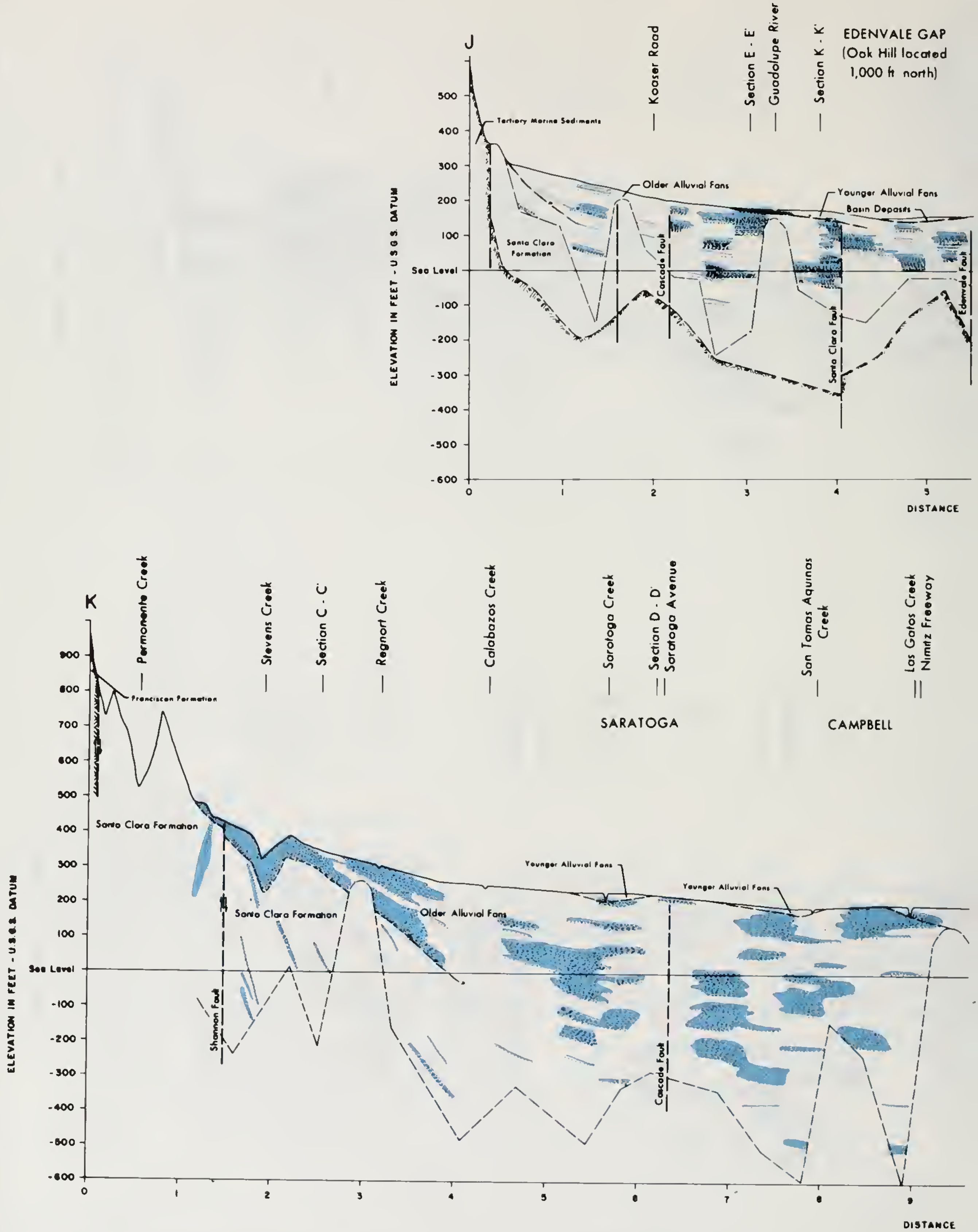


# GEOLOGIC SECTIONS

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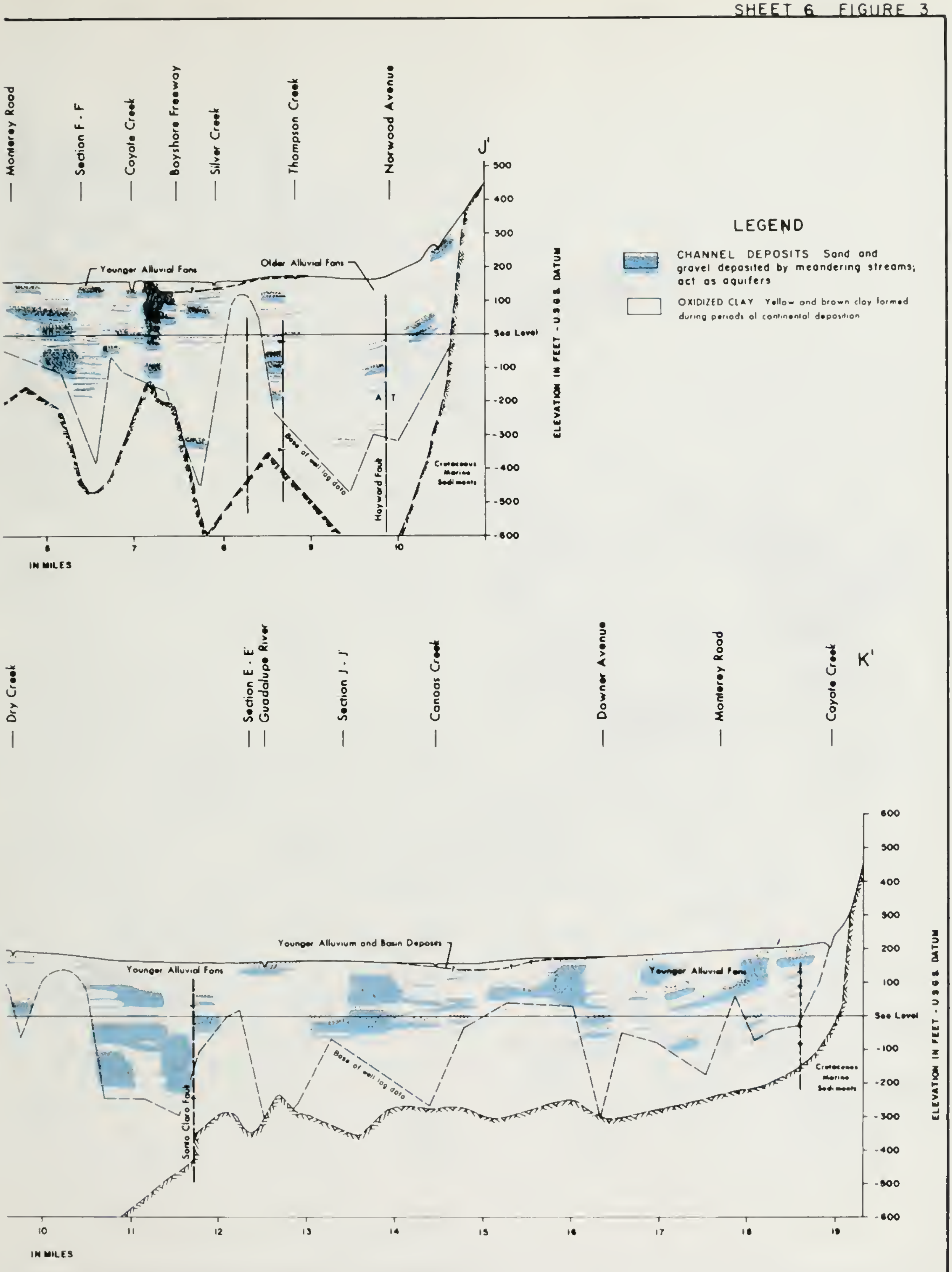
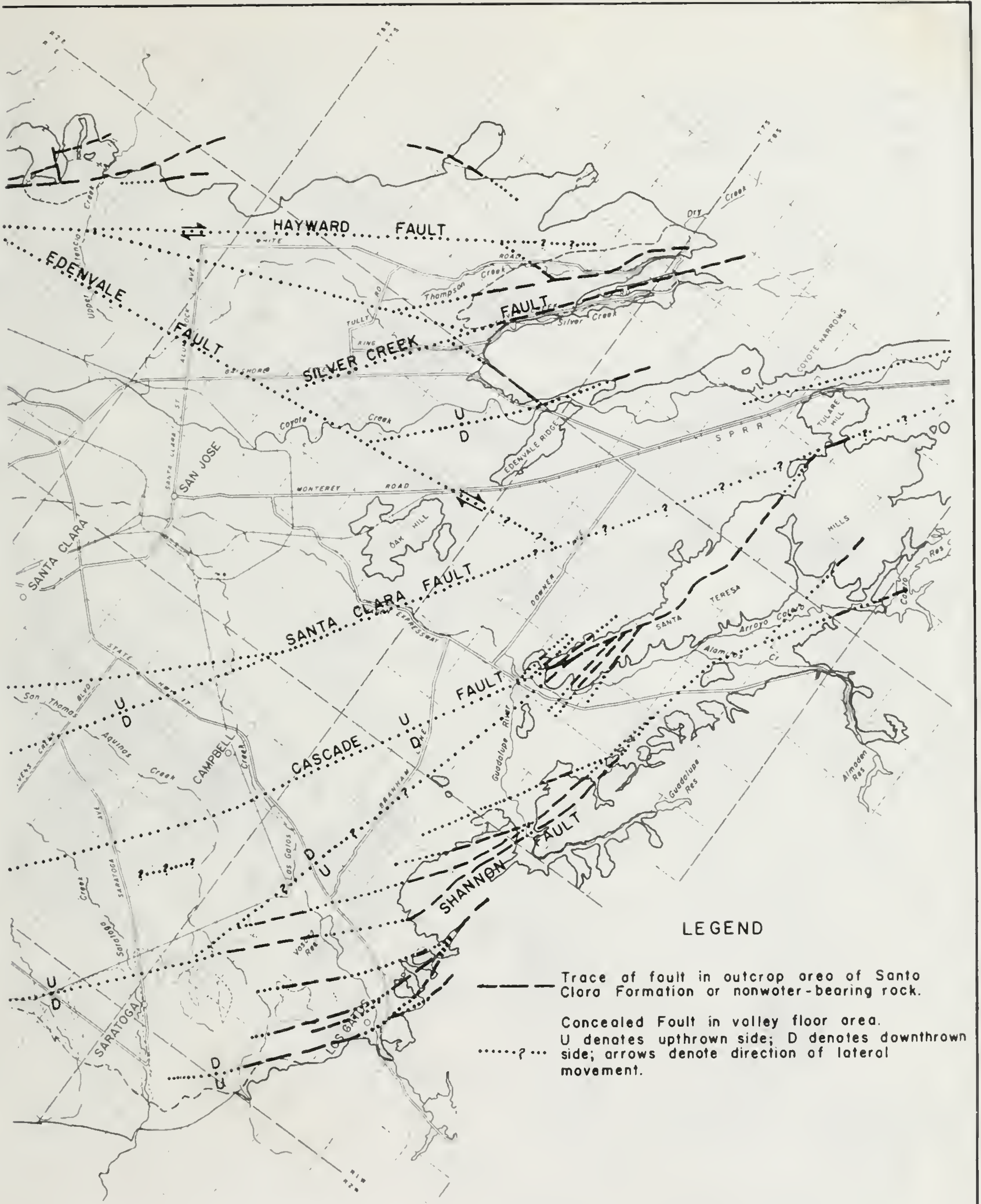



SANTA CLARA VALLEY

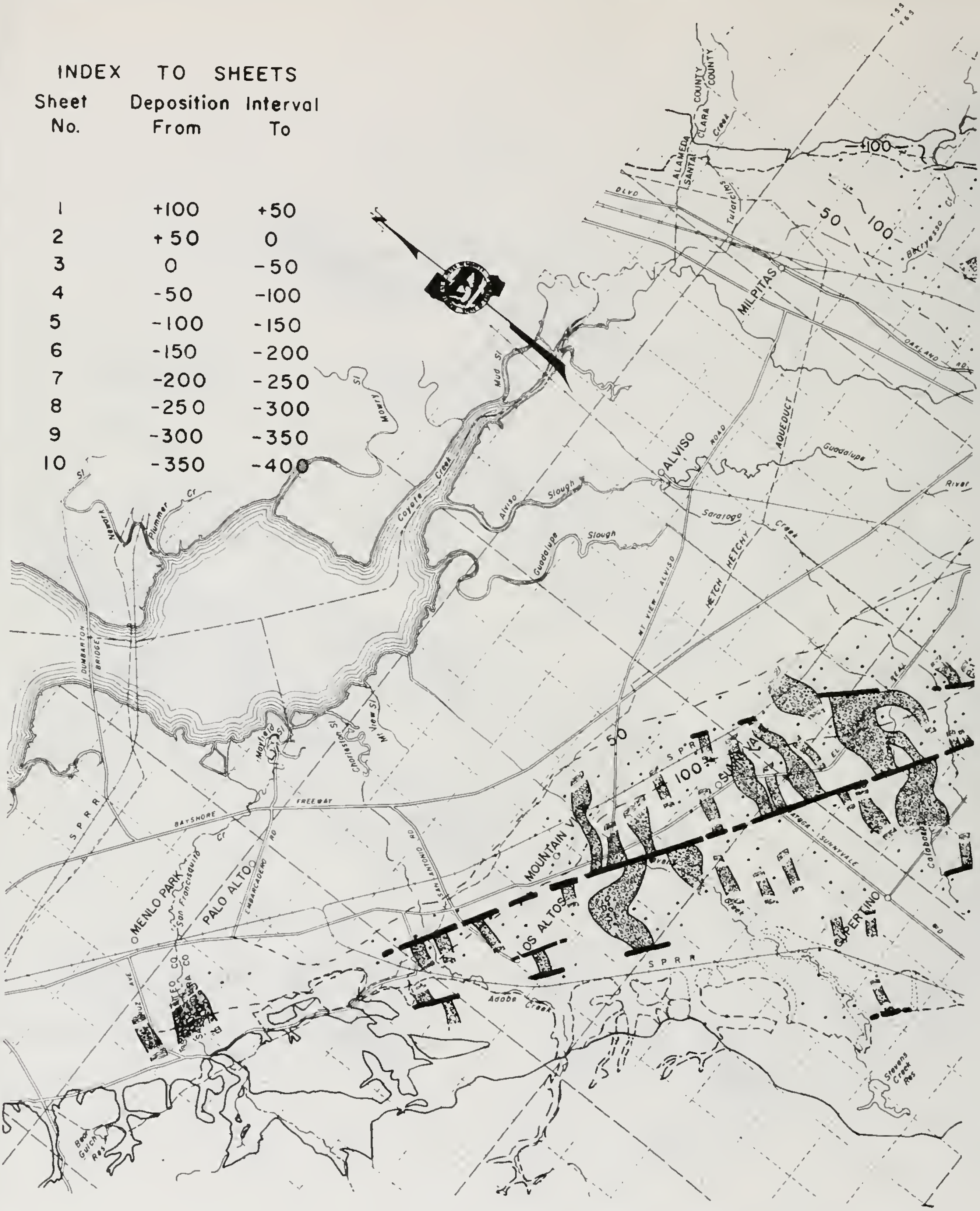

# FAULT TRACES IN




# SANTA CLARA VALLEY

## INDEX TO SHEETS

| Sheet No. | Deposition Interval From | To |
|---|---|---|
| 1 | +100 | +50 |
| 2 | +50 | 0 |
| 3 | 0 | -50 |
| 4 | -50 | -100 |
| 5 | -100 | -150 |
| 6 | -150 | -200 |
| 7 | -200 | -250 |
| 8 | -250 | -300 |
| 9 | -300 | -350 |
| 10 | -350 | -400 |




# ELEVATION +100

# SUBSURFACE DEPOSITION


TO +50 FEET

SANTA CLARA VALLEY


# ELEVATION +50

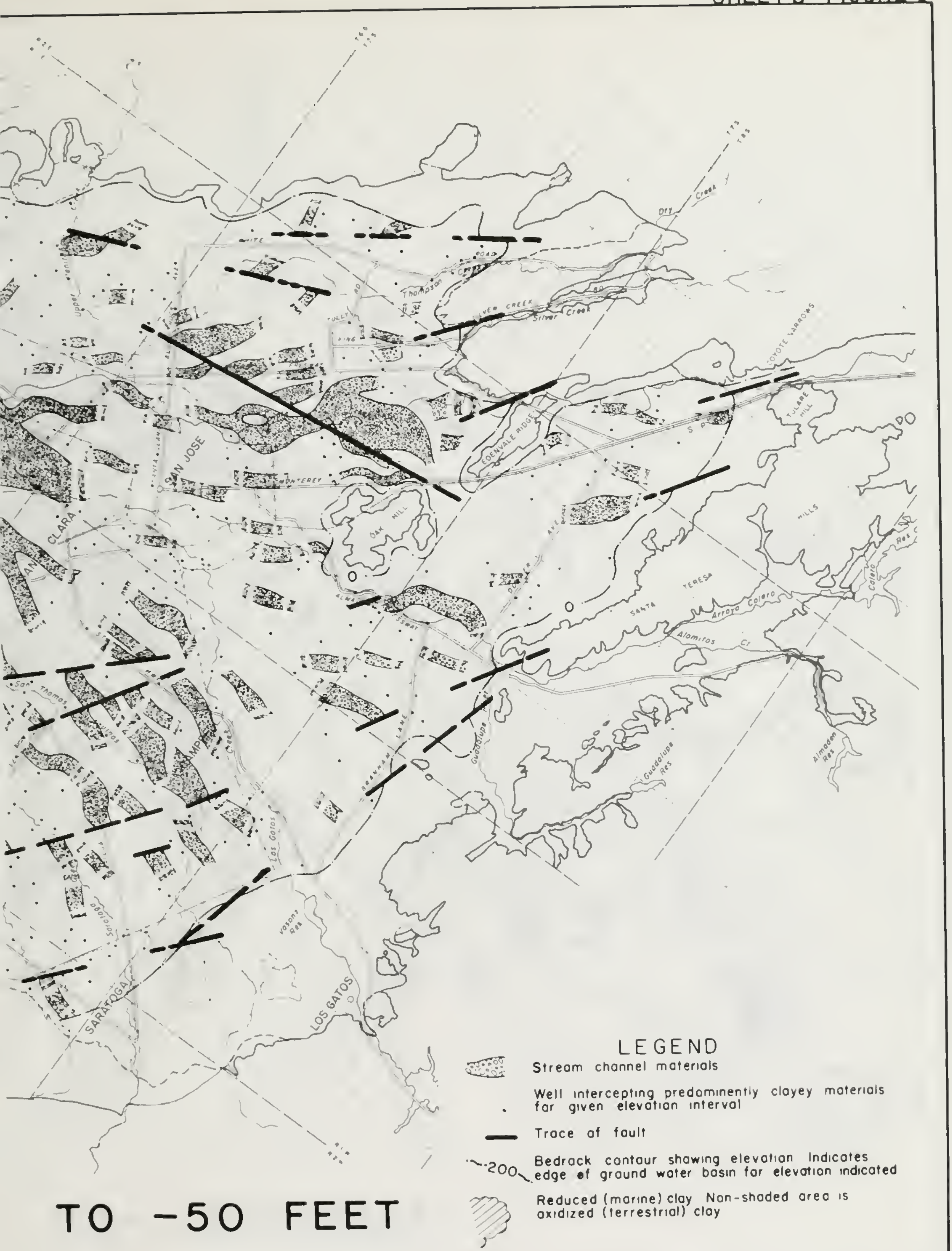
# SUBSURFACE DEPOSITION


# TO 0 FEET

# SANTA CLARA VALLEY

# ELEVATION 0

# SUBSURFACE DEPOSITION




# TO −50 FEET

# SANTA CLARA VALLEY


# ELEVATION −50

# SUBSURFACE DEPOSITION


TO −100 FEET

SANTA CLARA VALLEY


# ELEVATION −100

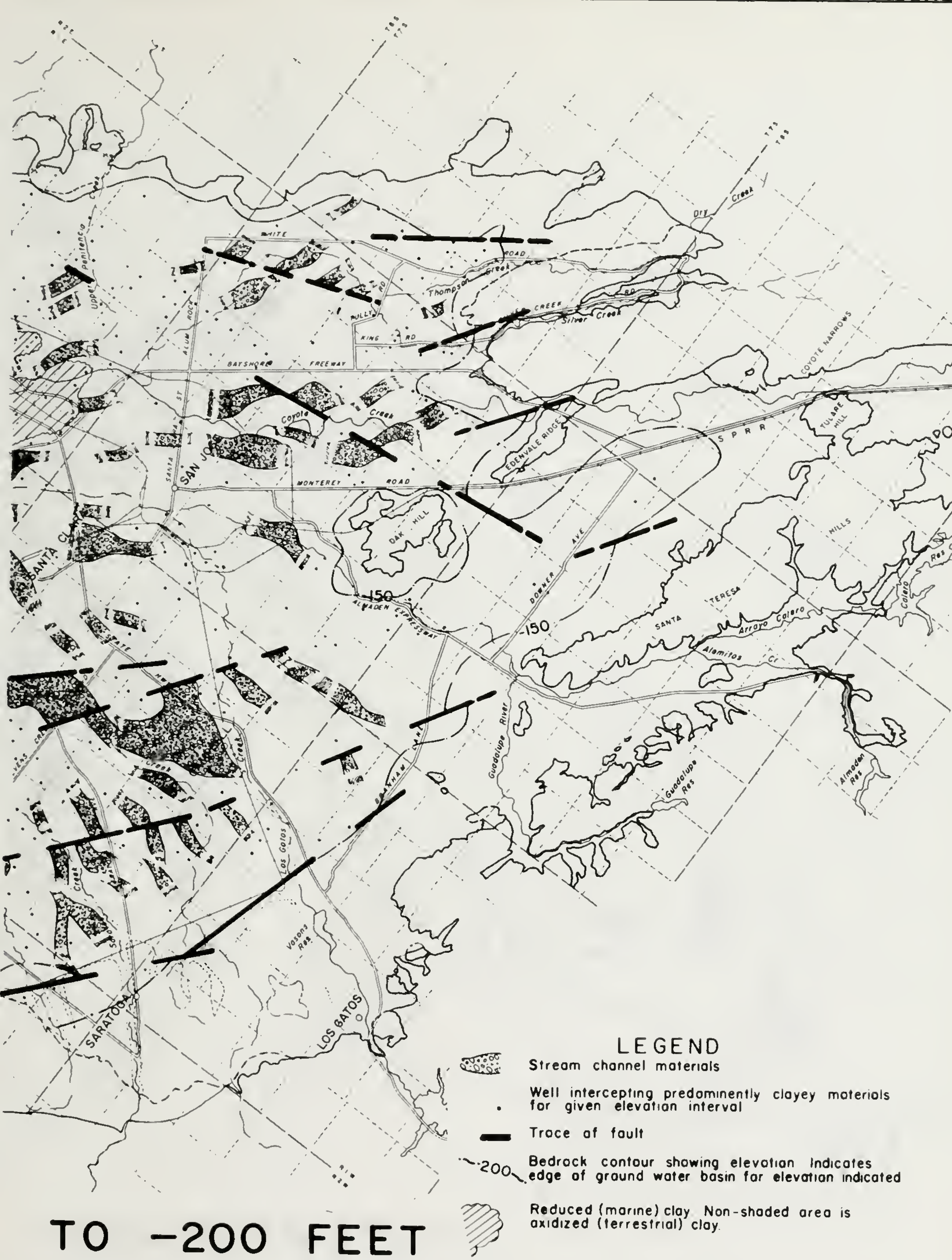
# SUBSURFACE DEPOSITION


# TO -150 FEET

# SANTA CLARA VALLEY


## ELEVATION –150

# SUBSURFACE DEPOSITION

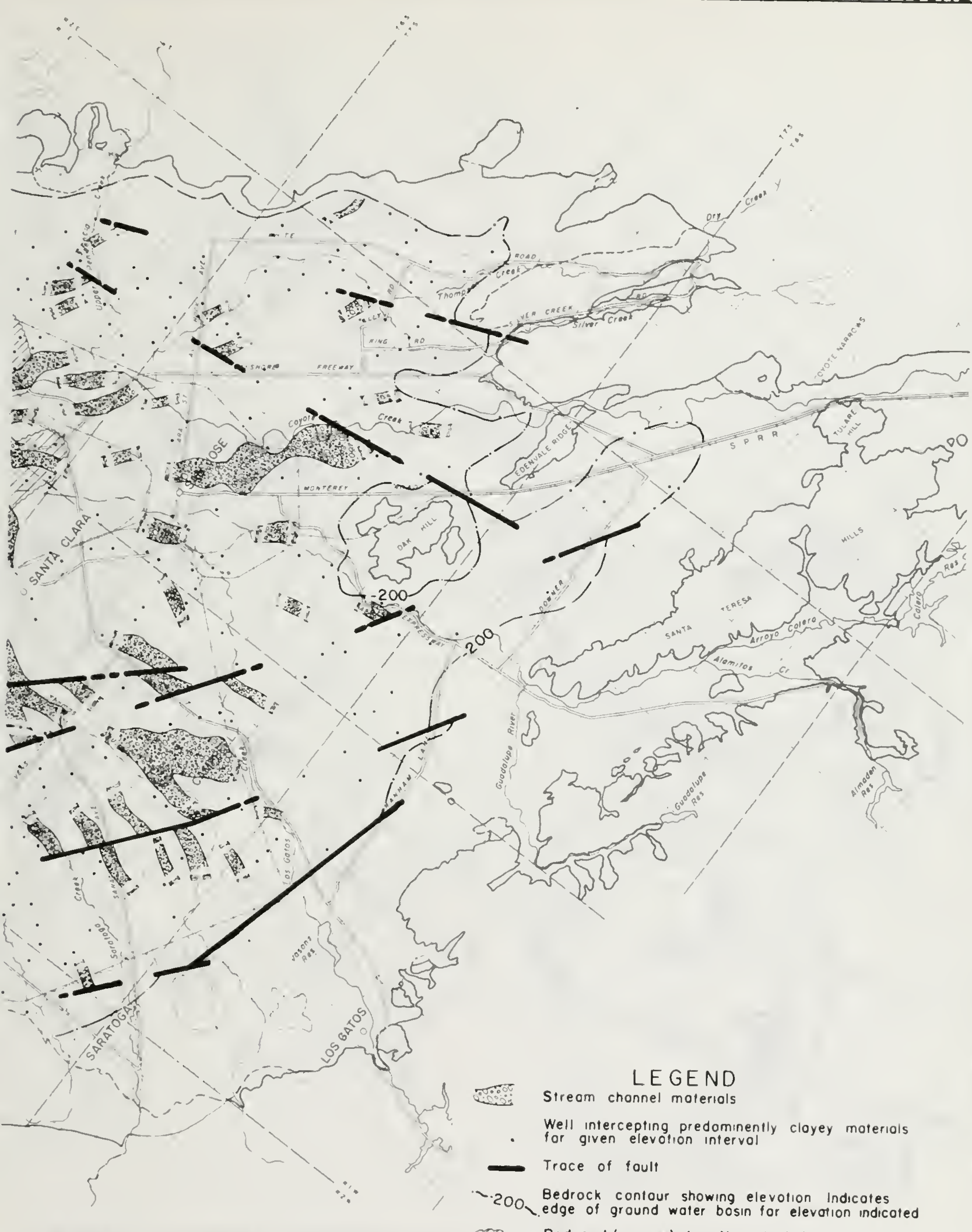



# TO -200 FEET

# SANTA CLARA VALLEY


# ELEVATION −200

# SUBSURFACE DEPOSITION

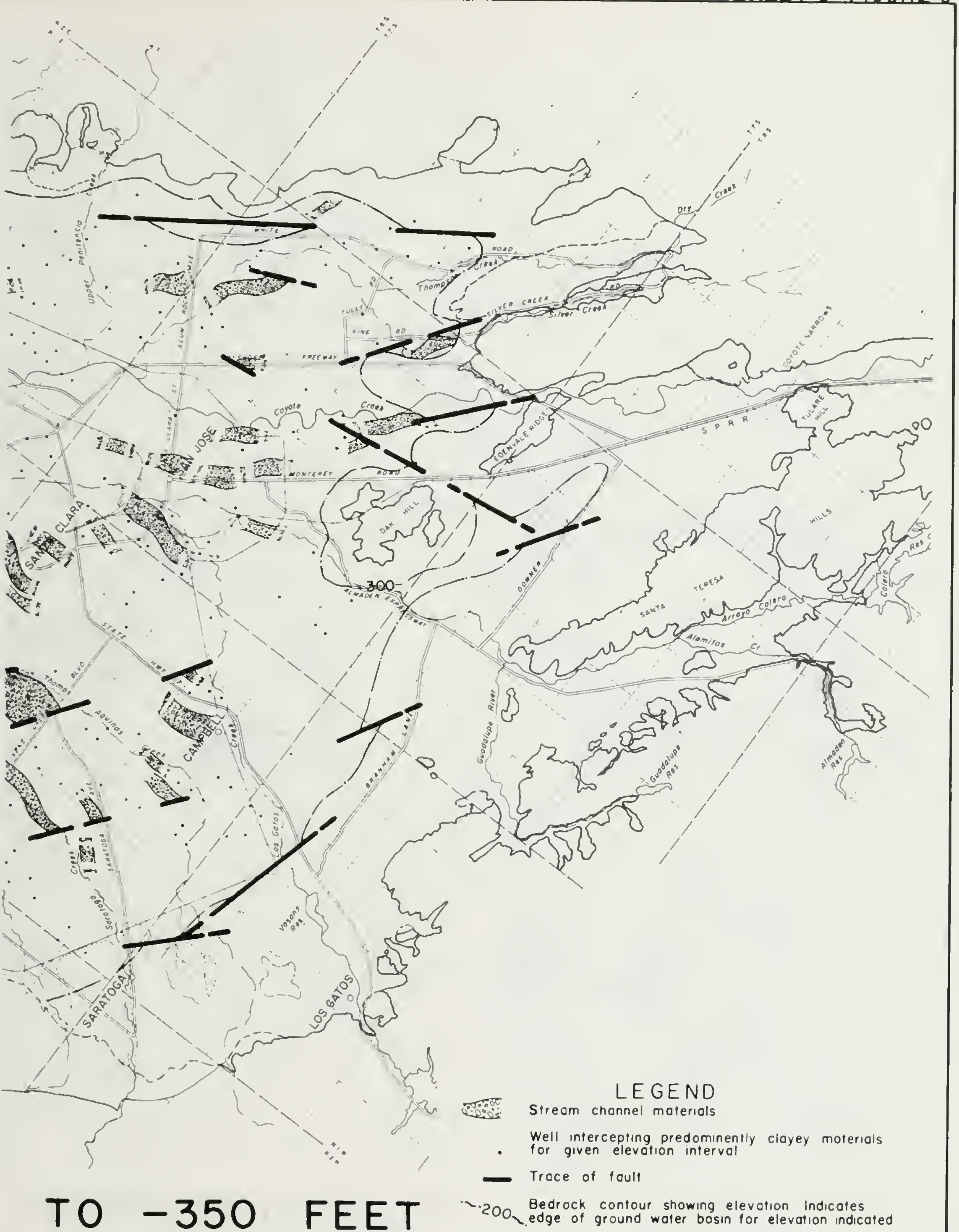



TO −250 FEET

SANTA CLARA VALLEY


# ELEVATION —300

# SUBSURFACE DEPOSITION

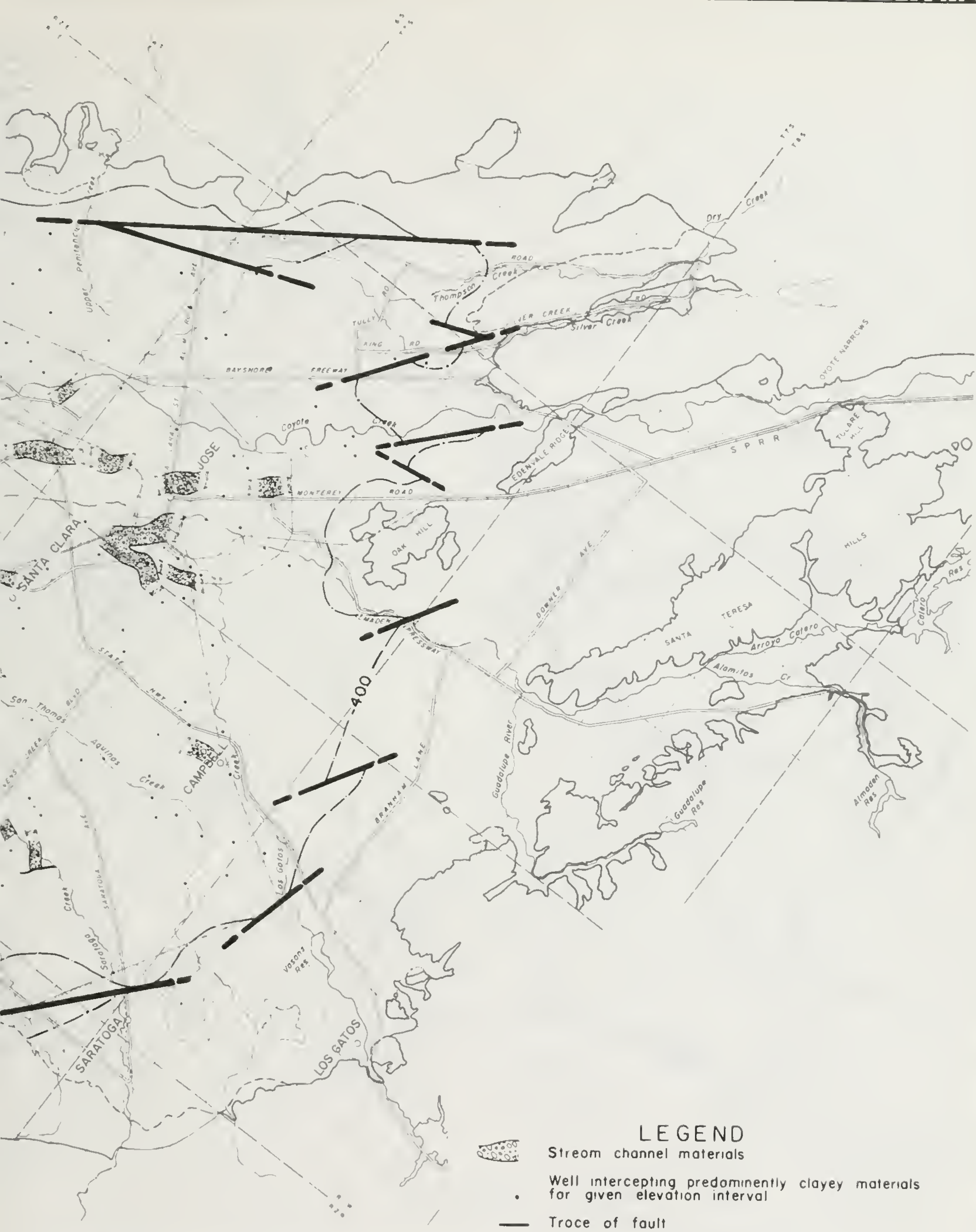



# TO −350 FEET

# SANTA CLARA VALLEY


ELEVATION -400

SUBSURFACE DEPOSITION




LEGEND

Streom chonnel moteriols

• Well intercepting predominently clayey moteriols for given elevation interval

— Troce of fault

200 Bedrock contour showing elevation Indicates edge of ground water bosin for elevation indicated

# TO −450 FEET

# SANTA CLARA VALLEY


# ELEVATION −500′

## SUBSURFACE DEPOSITION


## TO −550 FEET

**LEGEND**

- Stream channel materials
- Well intercepting predominently clayey materials for given elevation interval
- Trace of fault
- 200 Bedrock contour showing elevation. Indicates edge of ground water basin for elevation indicated

# SANTA CLARA VALLEY

# CHAPTER IV. EVALUATION OF HISTORIC WATER SUPPLY AND DISPOSAL

The evaluation of the ground water system with regard to the acceptance, storage, and transmission of water is obtained by the development of an inventory of supply to and disposal from the ground water body. The ability of the system to store and transmit water under changing conditions can be evaluated by superimposing the works of man on natural hydrologic events such as precipitation, recharge, and consumptive use and then determining the reaction of the ground water system using the previously developed geologic information.

A ground water system can be described as many zones of gravel and sand separated from each other by zones of clay and having some degree of interconnection. This ground water system is only a portion or subsystem of the entire hydrologic system; the interrelationships of each part of the hydrologic system is shown schematically in Figure 6.

An analysis of the ground water system is made by using a specific historic period. The reference, or base, used in the ground water analysis is the amount of ground water in storage. This is derived by making an inventory on an annual basis using the assumption that water which percolates below the root zone will reach the ground water body during the same water year. The analysis is stated by the equation:

Supply - Withdrawal = Change in storage

The items of supply, or recharge, to the ground water body are derived mainly from the following:

1. Precipitation infiltrating to ground water.

2. Storm runoff, or streamflow, including imported water released into natural channels and adjacent ponds infiltrating to ground water.

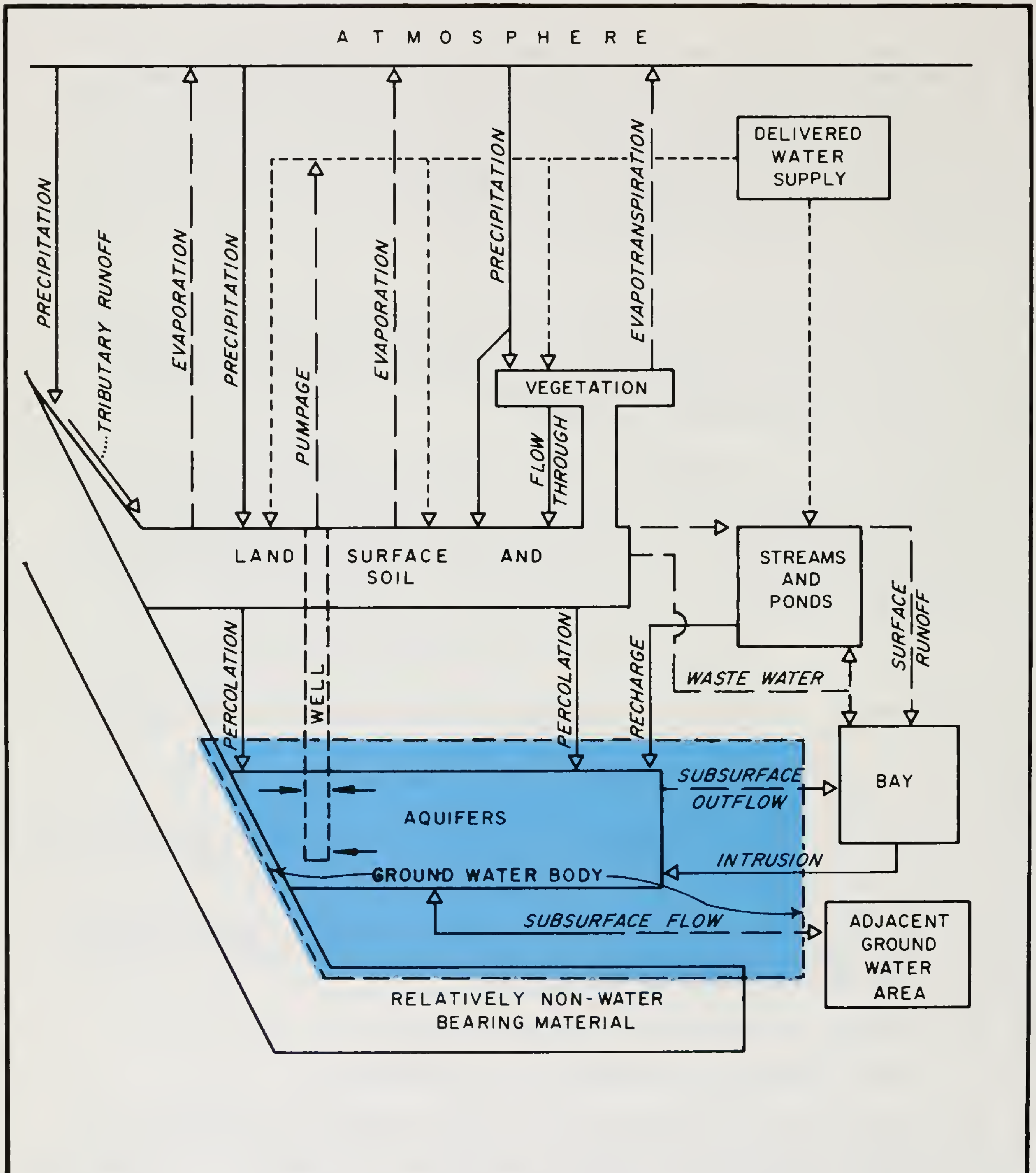
3. Applied water infiltrating to ground water. Applied water includes both pumped ground and imported water put directly into water distribution systems.

4. Subsurface inflow from adjacent areas.

5. Water released by compaction of clay beds.

Withdrawals from the ground water body consist of ground water pumpage and subsurface outflow from the basin. From the values for each of the above items, the change in storage is computed as the annual volume of ground water gained or lost from storage. A negative value indicates a depletion of ground water in storage.

FIGURE 6




HYDROLOGIC SYSTEM (SCHEMATIC)

Some of the items in the ground water inventory are directly measurable, some must be calcaulated, and some were measured for only a part of the study period and calculated for the remainder thereof. Of items that were calculated, most were on a water year basis (October 1 through September 30). The principal exception is ground water pumpage, which was calculated on a calendar year basis. Because each calendar year and water year contain the same summer period, and this period is when the variation in pumpage will occur, use of differing type of years has a minor effect.

The result of the ground water inventory is a theoretical change in the amount of water in storage. The accuracy of the analysis can be gaged by how close the calculated change in storage based on historic water levels compares with the net difference between recharge to and withdrawals from the ground water system.

The inventory is done on two bases: the first treats for the basin as a whole; and second subdivides the ground water area into many small units and uses. These units in a mathematical model were prepared to simulate the hydrologic system of the study area and to provide a means for testing the reaction of the ground water system to alternative plans. The model was programmed on computers to permit economic solution of repetitious computations.

## Ground Water Model

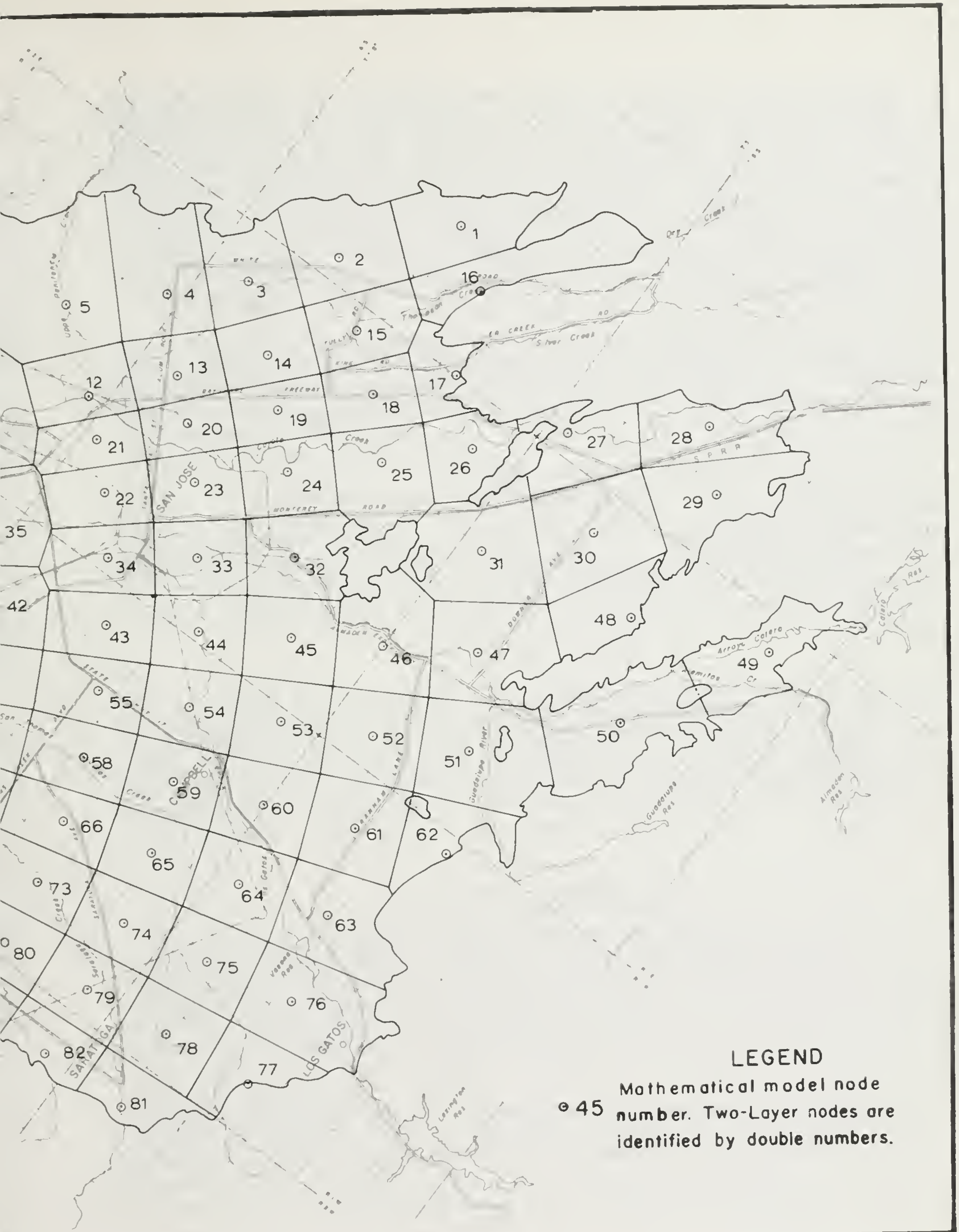
The ground water area shown on Figure 1 has been approximated by the mathematical model shown in Figure 7. In the model configuration, the orientation of the individual nodal areas is based on detailed geologic and hydrologic interpretations. The northern end of the study area is an area of overlap of deposition from Alameda Creek and the various Santa Clara County streams. This condition of overlap has been simulated by using Nodes 8, 38, 39, 94, and 99 of the Santa Clara model in the mathematical model of the adjacent Fremont ground water area. This latter model is discussed in detail in Bulletin 118-1: "Evaluation of Ground Water Resources: South San Francisco Bay: Volume II: Additional Fremont Area Study".

Confinement in the lower portion of the present study area has been simulated by using three layers, two aquifers separated by a confining bed. The areas of lower confinement are shown on Figure 7 by double node numbers; the lower aquifer portions of the nodes are numbered 100 through 116.

The amounts of recharge, withdrawal, and change in storage have been determined for each nodal area in the model. In this bulletin, many of the results have been summarized and reported only for the total ground water area, but detailed nodal information is available in the department files.


MATHEMATICAL MODEL

FIGURE 7




# NODAL NETWORK

In northern Santa Clara County, the ground water system consists of many related tabular aquifers. Water wells in the study area usually have been constructed to tap most of the aquifers penetrated. This makes it nearly impossible to determine the amounts of water extracted from particular aquifers and hence makes it necessary to evaluate the series of aquifers as if it were only a single aquifer. The only exception to this is in the area adjacent to the Bay, where the existence of a thick, extensive clay layer permits the series of aquifers to be divided into two distinct zones.

Analysis of water levels for individual wells in the study area indicates that composite water levels for different combinations of aquifers tend to be nearly parallel to each other. This permits the use of most of the available water level data to determine annual changes in water levels for the total aquifer system. It does not, however, permit the identification of those water levels which represent the potentiometric surface of the free (unconfined) ground water. Measurements representing this free ground water surface are not available for the study period in most of the ground water area. Because complete validation of the mathematical model is dependent on matching model-developed water levels against historic free ground water levels, the validity of the present model could not be established at the level of reliability desired for detailed evaluation of alternative plans.

The inability to obtain complete validation of the model is not a serious problem because the validity of the hydrology has been established by the verification of the hydrologic balance for the entire basin. The model can be used as a general planning tool but should be used with care in the evaluation of alternative plans. The historic ground water measurements and proposed changes in the monitoring network are discussed in Chapter V.

## Study Period

In selection of a segment of time to use as a study period, it is desirable to specify certain criteria. The hydrologic conditions during the study period should represent the long-time hydrologic conditions. Furthermore, the selected time segment should begin at the end of a dry period and should end at the conclusion of another dry period in order to minimize any difference between the amount of water in transit prior to both the beginning and the end of the study period. The change in water levels from the beginning to the end of the study period should also be minimal in order to avoid the effects of perched water and water in transit. Finally, the time segment should be within the period of available records and should include recent changes in land utilization to aid in the determination of the effect of these changes on the recharge of ground water.

This report uses an eight-year study period, 1962-63 through 1969-70. The year 1962-63 was selected as the initial year because it is preceded by a year of subnormal precipitation, represents conditions prior to importation of additional water supplies, and is the start of a period of generally above-average rainfall. This latter condition permitted easier conversion of results to normal or average rainfall conditions. The chosen study period is not entirely ideal, however, because the initial year is preceded by several consecutive dry years, while the ending year is preceded by only one such year. In addition, a large recovery of water levels has taken place during the study period. It should be noted that the artificial recharge of ground water is the major source of ground water replenishment, making variations of precipitation less important. The relationship of precipitation during the long-term and the study period is shown on Figure 8.

## Precipitation

The yearly amounts of rainfall at San Jose and their variations from the average are shown in Table 4. Variations in average precipitation over the study area are shown on Figure 9.

## Tributary Runoff

Only a small portion of the drainage area tributary to Santa Clara Valley is gaged. Runoff from the remaining area was determined by developing runoff-precipitation relationships for the gaged areas and applying the relationships to the ungaged areas. Table 5 lists the tributary watersheds and the annual amounts of estimated runoff. The locations of tributary drainage areas are shown on Figure 10.

Estimates of tributary stream runoff from the west and the east hilly areas (most of which are ungaged) into the valley floor were made on the rainfall -- runoff correlations at representative (usually nearby) gaged basins. For developing correlation curves, seasonal stream runoff (in inches) was plotted against the seasonal basin precipitation (in inches). A straight line correlation of the data points fitted very well within the range of the data studied. The straight line has an intercept (b) on the abscissa, which is the amount of precipitation that would be consumed prior to the initiation of runoff.

Seasonal runoff from an ungaged area can be computed from the following formula when runoff data from a nearby gaged area and precipitation data for the two areas are available:

$$R_u = R_g\ (P_u - b)/(P_g - b),$$

where $R_u$ = Seasonal runoff from ungaged area, in inches,

$R_g$ = Seasonal runoff from representative gaged area, in inches,

$P_u$ = Seasonal precipitation on the ungaged area, in inches,

$P_g$ = Seasonal precipitation on the representative gaged area, in inches, and

$b$ = Precipitation, in inches, that would be consumed prior to initiation of runoff.

Similarly, the annual basin precipitation can be estimated by the following formula if mean seasonal precipitation data are available:

$$P_a = (P_i \cdot P_a')/(P_a' \cdot P_i'),$$

where $P_a$ = Annual basin precipitation, in inches,

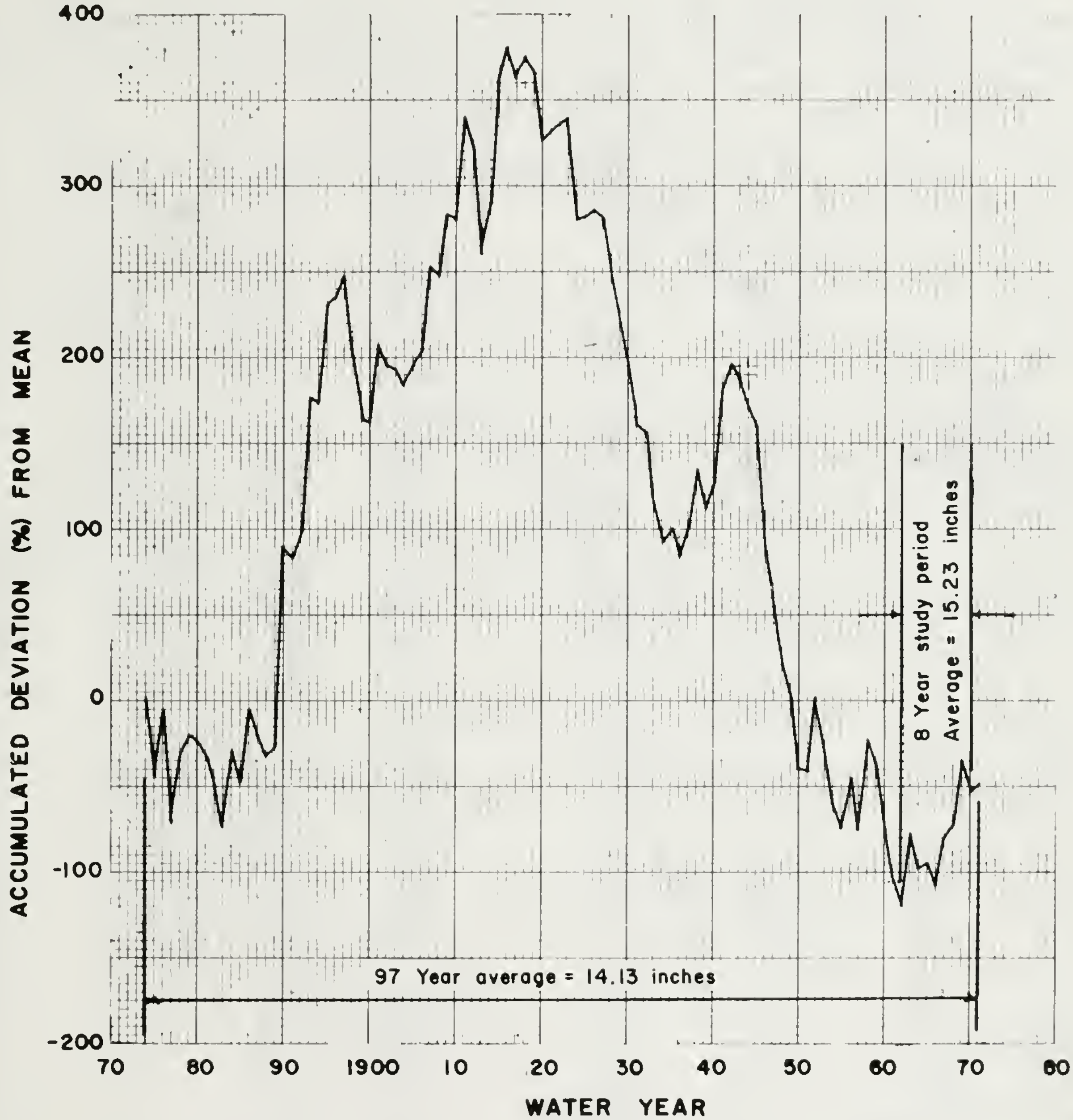
$P_a'$ = Mean seasonal basin precipitation, in inches, estimated from isohyetal map,

$P_i$ = Seasonal precipitation at nearby index station, in inches, and

$P_i'$ = Mean seasonal precipitation at nearby index station, in inches.

## Imported Water

The need for additional water on a large scale from distant sources was first envisioned by the City of San Francisco. In 1934, the Hetch Hetchy Project was completed and began delivering water to the Bay Area. This water, however, was not available to Santa Clara County users until 1952 when an 80 MGD (302,000 $m^3/d$) pipeline extension was completed across the north valley. A second parallel pipeline was finished in 1974. The Hetch Hetchy system now supplies water to the Cities of Palo Alto, San Jose, Sunnyvale, Mountain View, Milpitas, and Santa Clara, as well as Purissima Hills County Water District, Stanford University, Moffett Field and NASA, and Agnews State Hospital. The water is entirely for municipal and industrial use. Hetch Hetchy imports to these cities increased steadily to nearly 50,000 acre-feet (62 $hm^3$) in 1973, which was 20 percent of the total annual demand of northern Santa Clara County. The annual amounts of imports from the Hetch Hetchy system are shown in Table 6.




LONG TERM PRECIPITION AT SAN JOSE

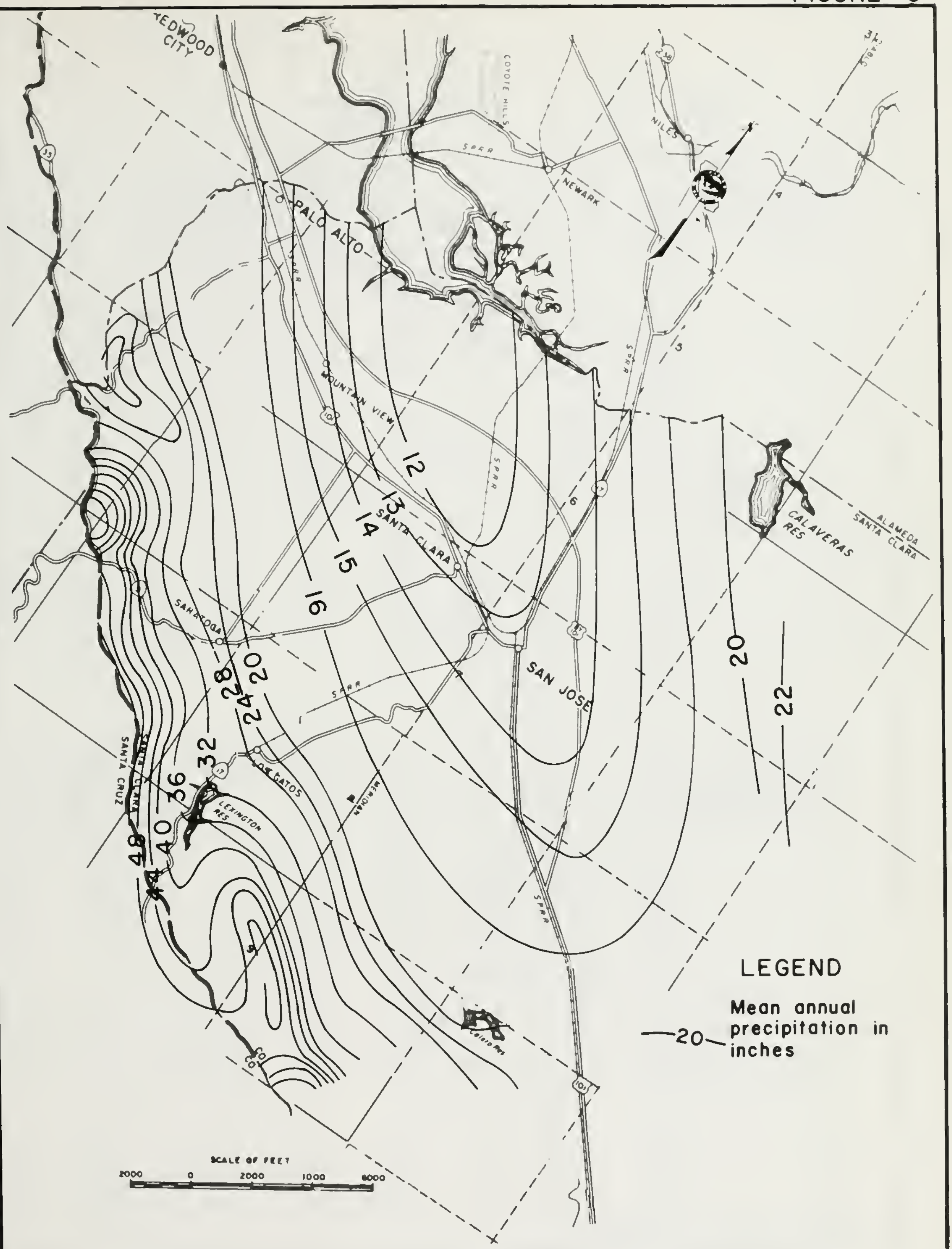
TABLE 4

ANNUAL PRECIPITATION AND INDEX OF WETNESS
AT SAN JOSE

1874-1971

| Water Year | Precipitation | | Index of Wetness | Water Year | Precipitation | | Index of Wetness |
|---|---|---|---|---|---|---|---|
| | Inches | Centimeters | | | Inches | Centimeters | |
| 1874-75 | 7.80 | *19.81* | 55.2 | | | | |
| 1875-76 | 19.59 | *49.76* | 138.6 | 1925-26 | 14.44 | *36.68* | 102.2 |
| 76-77 | 4.72 | *11.98* | 33.4 | 26-27 | 13.90 | *35.31* | 98.4 |
| 77-78 | 19.76 | *50.19* | 139.8 | 27-28 | 10.09 | *25.63* | 71.4 |
| 78-79 | 15.92 | *40.44* | 112.7 | 28-29 | 10.14 | *25.76* | 71.8 |
| 79-80 | 13.80 | *35.05* | 97.7 | 29-30 | 10.89 | *27.66* | 77.1 |
| 1880-81 | 12.47 | *31.67* | 88.3 | 1930-31 | 8.30 | *21.08* | 58.7 |
| 81-82 | 11.77 | *29.89* | 82.3 | 31-32 | 13.40 | *34.04* | 94.8 |
| 82-83 | 11.44 | *29.06* | 81.0 | 32-33 | 8.90 | *22.61* | 63.0 |
| 83-84 | 20.07 | *50.98* | 142.0 | 33-34 | 8.97 | *22.78* | 63.5 |
| 84-85 | 11.19 | *28.42* | 79.2 | 34-35 | 16.49 | *41.88* | 116.7 |
| 1885-86 | 20.66 | *52.48* | 146.2 | 1935-36 | 11.90 | *30.23* | 84.2 |
| 86-87 | 11.96 | *30.38* | 84.6 | 36-37 | 16.90 | *42.43* | 119.6 |
| 87-88 | 12.14 | *30.84* | 85.9 | 37-38 | 18.75 | *47.63* | 132.7 |
| 88-89 | 15.11 | *38.38* | 106.9 | 38-39 | 10.77 | *27.36* | 76.2 |
| 89-90 | 30.35 | *77.09* | 214.8 | 39-40 | 16.35 | *41.53* | 115.7 |
| 1890-91 | 13.20 | *33.53* | 93.4 | 1940-41 | 21.25 | *53.98* | 150.4 |
| 91-92 | 16.14 | *40.99* | 114.2 | 41-42 | 16.56 | *42.06* | 117.2 |
| 92-93 | 25.17 | *63.93* | 178.1 | 42-43 | 13.13 | *33.35* | 92.9 |
| 93-94 | 14.00 | *35.56* | 99.1 | 43-44 | 11.47 | *29.13* | 81.2 |
| 94-95 | 22.29 | *56.62* | 157.7 | 44-45 | 12.44 | *31.60* | 88.0 |
| 1895-96 | 14.71 | *37.36* | 104.1 | 1945-46 | 11.26 | *28.60* | 79.7 |
| 96-97 | 15.70 | *39.88* | 111.1 | 46-47 | 9.00 | *22.86* | 63.7 |
| 97-98 | 7.79 | *19.79* | 55.1 | 47-48 | 9.89 | *25.12* | 70.0 |
| 98-99 | 8.79 | *22.33* | 62.2 | 48-49 | 11.59 | *29.44* | 82.0 |
| 99-00 | 14.06 | *35.71* | 99.5 | 49-50 | 8.31 | *21.11* | 58.8 |
| 1900-01 | 20.13 | *51.13* | 142.5 | 1950-51 | 14.12 | *35.86* | 99.9 |
| 01-02 | 12.54 | *31.85* | 88.7 | 51-52 | 19.57 | *49.71* | 138.5 |
| 02-03 | 13.89 | *35.28* | 98.3 | 52-53 | 9.67 | *24.56* | 68.4 |
| 03-04 | 12.66 | *32.16* | 89.6 | 53-54 | 9.99 | *25.37* | 70.7 |
| 04-05 | 15.77 | *40.06* | 111.6 | 54-55 | 11.85 | *30.10* | 83.9 |
| 1905-06 | 15.22 | *38.66* | 107.7 | 1955-56 | 18.54 | *47.09* | 131.2 |
| 06-07 | 22.64 | *57.51* | 160.2 | 56-57 | 9.86 | *25.04* | 69.8 |
| 07-08 | 11.99 | *30.45* | 84.9 | 57-58 | 21.71 | *55.14* | 153.6 |
| 08-09 | 18.97 | *48.18* | 134.3 | 58-59 | 11.75 | *29.85* | 83.2 |
| 09-10 | 13.90 | *35.31* | 98.4 | 59-60 | 8.39 | *21.31* | 59.4 |
| 1910-11 | 22.56 | *57.30* | 159.7 | 1960-61 | 10.05 | *25.53* | 71.1 |
| 11-12 | 11.30 | *28.70* | 80.0 | 61-62 | 12.44 | *31.60* | 88.0 |
| 12-13 | 5.81 | *14.76* | 41.1 | 62-63 | 20.49 | *52.04* | 145.0 |
| 13-14 | 19.28 | *48.97* | 136.5 | 63-64 | 10.29 | *26.14* | 72.8 |
| 14-15 | 22.75 | *57.79* | 161.0 | 64-65 | 15.09 | *38.33* | 106.8 |
| 1915-16 | 17.06 | *43.33* | 120.7 | 1965-66 | 10.81 | *27.46* | 76.5 |
| 16-17 | 11.86 | *30.12* | 83.9 | 66-67 | 19.62 | *49.83* | 138.9 |
| 17-18 | 15.68 | *39.83* | 111.0 | 67-68 | 15.08 | *38.30* | 106.7 |
| 18-19 | 12.79 | *32.49* | 90.5 | 68-69 | 19.30 | *49.02* | 136.6 |
| 19-20 | 8.57 | *21.77* | 60.7 | 69-70 | 11.18 | *28.40* | 79.1 |
| 1920-21 | 15.21 | *38.63* | 107.6 | 1970-71 | 14.92 | *37.90* | 105.6 |
| 21-22 | 14.56 | *36.98* | 103.0 | | | | |
| 22-23 | 14.48 | *36.78* | 102.5 | | | | |
| 23-24 | 5.92 | *15.04* | 42.0 | | | | |
| 24-25 | 14.27 | *36.25* | 101.0 | | | | |

97 Year Average (1874-1971) = 14.13 inches (35.89 centimeters)




MEAN ANNUAL PRECIPITATION

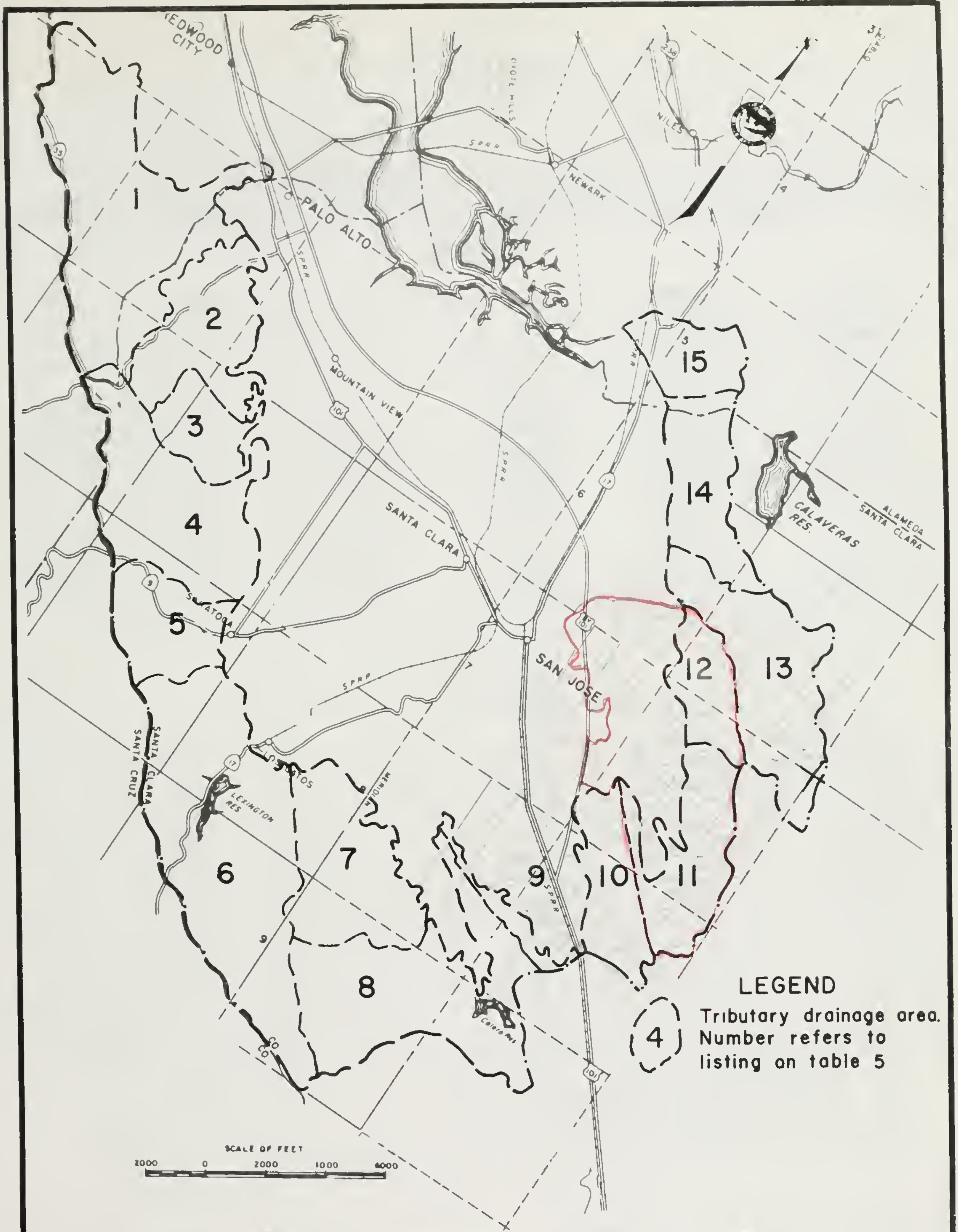
TABLE 5

TRIBUTARY RUNOFF

| Tributary Drainage Area* | Area (square miles) | Runoff (thousand acre-feet) 1962-63 | 1963-64 | 1964-65 | 1965-66 | 1966-67 | 1967-68 | 1968-69 | 1969-70 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 39.1 | 16.80 | 1.93 | 16.12 | 4.55 | 29.40 | 4.28 | 31.96 | 17.18 |
| 2 | 17.2 | 4.02 | 1.24 | 3.58 | 2.70 | 8.64 | 3.27 | 12.62 | 6.22 |
| 3 | 7.6 | 3.32 | 0.45 | 2.59 | 1.13 | 3.81 | 0.73 | 4.70 | 1.91 |
| 4 | 24.5 | 18.67 | 5.10 | 19.35 | 4.46 | 19.54 | 5.23 | 22.70 | 9.77 |
| 5 | 10.9 | 12.76 | 1.13 | 10.68 | 2.17 | 13.93 | 2.74 | 19.23 | 7.04 |
| 6 | 43.6 | 74.13 | 14.90 | 34.31 | 9.32 | 55.88 | 17.38 | 66.32 | 29.95 |
| 7 | 20.5 | 23.30 | 4.46 | 12.20 | 4.09 | 26.35 | 7.99 | 25.12 | 8.82 |
| 8 | 27.9 | 23.92 | 8.57 | 11.83 | 8.68 | 22.31 | 11.55 | 27.41 | 12.91 |
| 9 | 3.2 | 0.67 | 0.00 | 0.53 | 0.00 | 0.97 | 0.05 | 1.26 | 0.15 |
| 10 | 11.0 | 1.00 | 0.06 | 1.29 | 0.00 | 2.64 | 0.18 | 2.35 | 0.00 |
| 11 | 13.8 | 1.42 | 0.24 | 2.43 | 0.26 | 4.04 | 0.40 | 3.67 | 0.35 |
| 12 | 8.6 | 0.76 | 0.03 | 1.02 | 0.00 | 2.06 | 0.12 | 1.81 | 0.00 |
| 13 | 23.1 | 2.84 | 0.79 | 5.93 | 1.04 | 8.58 | 1.11 | 8.01 | 1.97 |
| 14 | 13.2 | 1.27 | 0.07 | 2.25 | 0.14 | 3.66 | 0.21 | 3.17 | 0.42 |
| 15 | 8.5 | 0.82 | 0.05 | 1.45 | 0.09 | 2.36 | 0.14 | 2.04 | 0.27 |

| Tributary Drainage Area* | Area (square kilometers) | Runoff (cubic hectometers) 1962-63 | 1963-64 | 1964-65 | 1965-66 | 1966-67 | 1967-68 | 1968-69 | 1969-70 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *101.3* | *20.66* | *2.37* | *19.83* | *5.60* | *36.16* | *5.26* | *39.31* | *21.13* |
| 2 | *44.5* | *4.94* | *1.53* | *4.40* | *3.32* | *10.63* | *4.02* | *15.52* | *7.65* |
| 3 | *19.7* | *4.08* | *0.55* | *3.19* | *1.39* | *4.69* | *0.90* | *5.78* | *2.35* |
| 4 | *63.5* | *22.96* | *6.27* | *23.80* | *5.49* | *24.03* | *6.43* | *27.92* | *12.02* |
| 5 | *28.2* | *15.64* | *1.39* | *13.14* | *2.67* | *17.13* | *3.37* | *23.65* | *8.66* |
| 6 | *112.9* | *91.18* | *18.33* | *42.20* | *11.46* | *68.73* | *21.38* | *81.57* | *36.84* |
| 7 | *53.1* | *28.66* | *5.49* | *15.01* | *5.03* | *32.41* | *9.83* | *30.90* | *10.85* |
| 8 | *72.3* | *29.42* | *10.54* | *14.55* | *10.68* | *27.44* | *14.21* | *33.71* | *15.88* |
| 9 | *8.3* | *0.82* | *0.00* | *0.65* | *0.00* | *1.19* | *0.06* | *1.55* | *0.18* |
| 10 | *28.5* | *1.23* | *0.07* | *1.59* | *0.00* | *3.25* | *0.22* | *2.89* | *0.00* |
| 11 | *35.7* | *1.75* | *0.29* | *2.99* | *0.32* | *4.97* | *0.49* | *4.51* | *0.43* |
| 12 | *22.3* | *0.93* | *0.04* | *1.25* | *0.00* | *2.53* | *0.15* | *2.23* | *0.00* |
| 13 | *59.8* | *3.49* | *0.97* | *7.29* | *1.28* | *10.55* | *1.37* | *9.85* | *2.42* |
| 14 | *34.2* | *1.56* | *0.09* | *2.77* | *0.17* | *4.50* | *0.26* | *3.90* | *0.52* |
| 15 | *22.0* | *1.01* | *0.06* | *2.78* | *0.11* | *2.90* | *0.17* | *2.51* | *0.33* |

*For location, see Figure 10.




TRIBUTARY DRAINAGE AREAS

Table 6

IMPORTED WATER

| Fiscal Year | Hetch Hetchy | State Water Project[1/] Ground Water Recharge | Tinconada Water Treatment Plant[2/] | Local Irrigation | Total |
|---|---|---|---|---|---|
| | | Acre-Feet | | | |
| 1962 | 15,490 | | | | -0- |
| 1963 | 23,140 | | | | -0- |
| 1964 | 27,090 | | | | -0- |
| 1965 | 29,590 | 500 | -0- | -0- | 500 |
| 1966 | 33,580 | 29,350 | -0- | -0- | 29,350 |
| 1967 | 36,040 | 31,460 | 310 | -0- | 31,770 |
| 1968 | 40,160 | 54,580 | 8,150 | 270 | 63,000 |
| 1969 | 42,180 | 45,640 | 11,450 | 570 | 57,660 |
| 1970 | 48,350 | 37,590 | 39,170 | 470 | 77,230 |
| 1971 | 45,210 | 43,790 | 43,990 | 710 | 88,490 |
| 1972 | 49,880 | 42,530 | 48,820 | 800 | 92,150 |
| 1973 | 48,890 | 46,990 | 44,990 | 600 | 92,580 |
| | | Cubic Hectometers[3/] | | | |
| 1962 | 19.1 | | | | -0- |
| 1963 | 28.5 | | | | -0- |
| 1964 | 33.4 | | | | -0- |
| 1965 | 36.5 | 0.6 | -0- | -0- | 0.6 |
| 1966 | 41.4 | 36.2 | -0- | -0- | 36.2 |
| 1967 | 44.4 | 38.8 | 0.4 | -0- | 39.2 |
| 1968 | 49.5 | 67.3 | 10.1 | 0.3 | 77.7 |
| 1969 | 52.0 | 56.3 | 14.1 | 0.7 | 71.1 |
| 1970 | 59.6 | 46.4 | 48.3 | 0.6 | 95.2 |
| 1971 | 55.8 | 54.0 | 54.2 | 0.9 | 109.1 |
| 1972 | 61.5 | 52.4 | 60.2 | 1.0 | 113.6 |
| 1973 | 60.3 | 57.9 | 55.5 | 0.8 | 114.2 |

1/ SBA deliveries began in June 1965.
2/ Rinconada Water Treatment Plant began operation in June 1967.
3/ Million cubic meters.

When it became evident that both locally developed water and Hetch Hetchy water would not keep pace with the growth, the Santa Clara Valley Water District contracted with the State to receive water from the State Water Project through the South Bay Aqueduct. Deliveries to the north valley began in July 1965 and presently total about 100,000 acre-feet (123 $hm^3$) a year. Deliveries include 88,000 acre-feet (109 $hm^3$) of contracted water and an additional 12,000 acre-feet (15 $hm^3$) of surplus water when available. Annual deliveries are listed in Table 6.

Approximately half of this imported water now is being treated for surface distribution at the Santa Clara Valley Water District Rinconada Water Treatment Plant, which was completed in 1967, and the Penitencia Water Treatment Facility, completed in 1974. The remainder is used for recharge of the ground water basin. The Penitencia Plant has capacity to treat 20 MGD (76,000 $m^3/d$) of South Bay Aqueduct water. The Rinconada and Penitencia Water Treatment Plants will eventually be treating nearly 70 percent of the total South Bay Aqueduct import. This will result in the reduction of imported water available for ground water recharge. Ground water levels have been recovering steadily since the initiation of water importation.

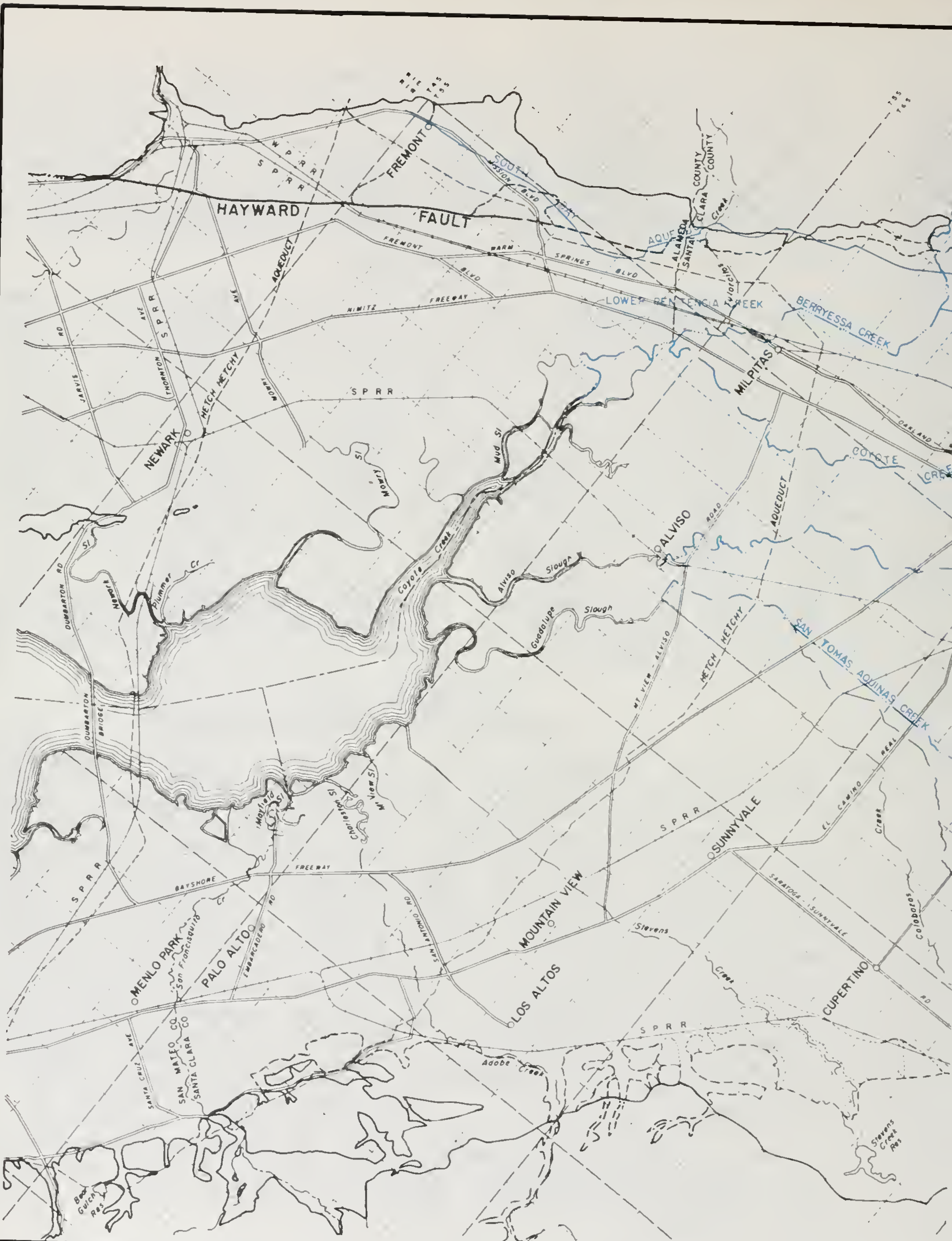
Increases in water demands have been supplied by treated imported water, so that ground water production has remained relatively constant at approximately 150,000 acre-feet (185 $hm^3$) per year.

## Operation of Recharge Facilities

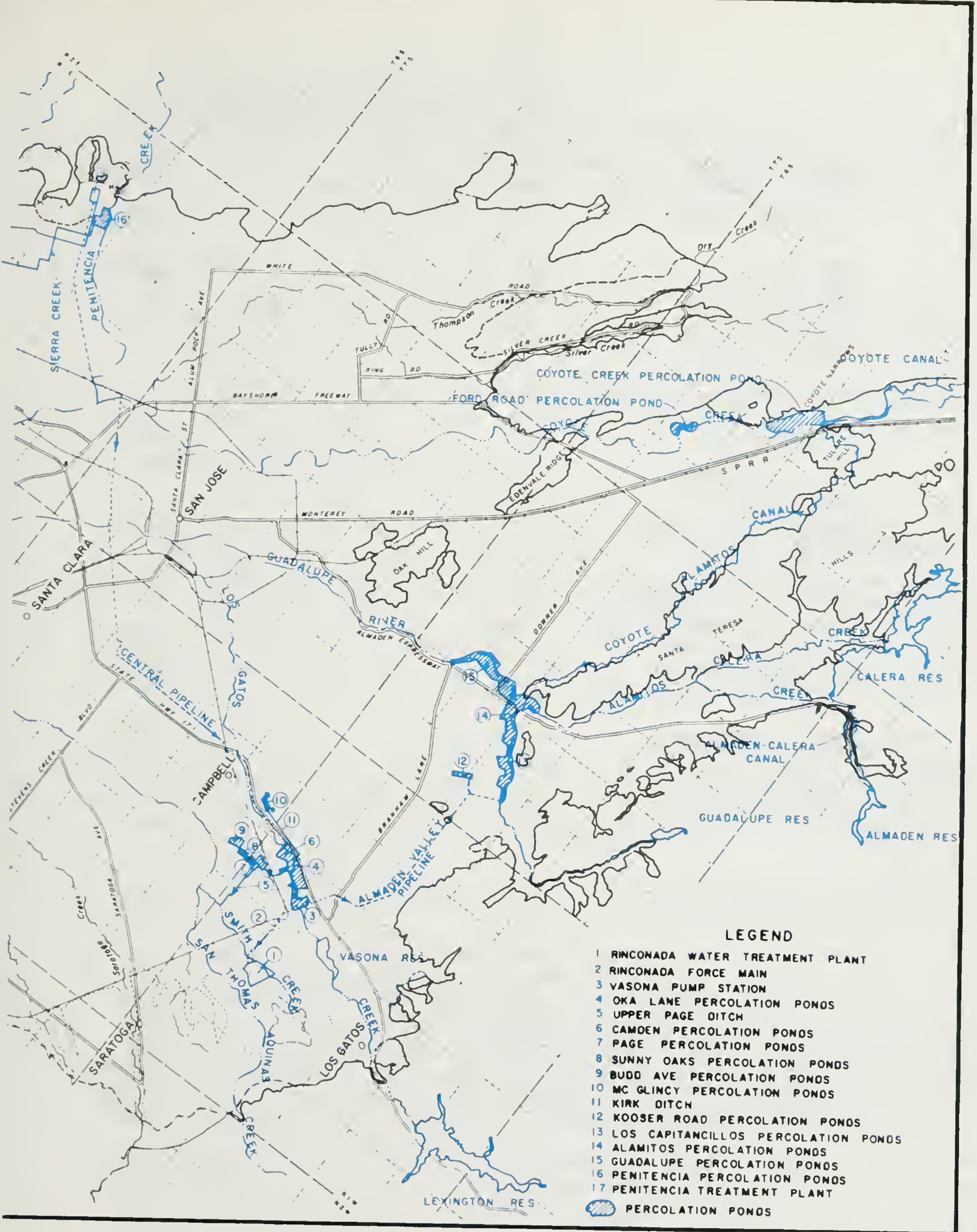
The primary purpose of the water retained in the various District reservoirs is to replenish the ground water basin. Water is released from the reservoirs to allow for its maximum use during the summer operation period. Annual analyses are made to determine the amounts of water available for recharge from the various reservoirs and the amounts of water available from imported water sources. The imported water available for recharge is that water not delivered to the Rinconada Water Treatment Plant or served directly for irrigation. An operational schedule is developed based on the amount of water available and on constraints such as maintenance and construction projects in natural channels and maintenance of recharge facilities. Recreational needs are met whenever possible. Those recharge facilities that are part of a park complex or leased to other agencies for recreation are operated whenever possible. Long-term recreational pools during the summer months are maintained if possible.

Reservoir releases are made to meet the downstream demands with the intention to maximize the total amount of water recharged. The areas of ground water deficiency would be first on a priority for recharge.

Data on percolation facilities are summarized in Table 7; Figure 11 shows the locations of the recharge facilities. Descriptive material on each facility is given below:




SANTA CLARA COUNTY




ARTIFICIAL RECHARGE SYSTEM

TABLE 7

PERCOLATION FACILITIES IN SANTA CLARA COUNTY

| Name | Location | Number of Ponds | Total Surface Area (acres) | Total Surface Area (hectares) | Maximum Recharge Rate (acre-feet per acre per day) | Maximum Recharge Rate (cubic meters per hectare per day) | Source of Water |
|---|---|---|---|---|---|---|---|
| Alamitos | On Guadalupe River at confluence of Alamitos and Guadalupe Creeks | 2 | 15 | 6.0 | 1 | 499.2 | Local and Imported |
| Budd | Along San Tomas Expressway near Budd Avenue | 3 | 9 | 3.6 | 3 | 1497.6 | Local and Imported |
| Camden | Along west bank Los Gatos Creek south of San Tomas Expressway | 3 | 62 | 25.1 | 0.5 | 249.6 | Local and Imported |
| Coyote | On Coyote River north of Metcalf Road and east of Highway 101 | 1 | 30 | 12.1 | 2 | 998.4 | Local |
| Ford Road | On Coyote River between Ford Road and Tennant Avenue | 4 | 34 | 13.7 | 1 | 499.2 | Local |
| Guadalupe | Along Guadalupe River north of Blossom Hill Road | 4 | 48 | 19.4 | 0.5 e/ | 249.6 e/ | Local and Imported |
| Kooser | Within PG&E right-of-way between Kooser Avenue and Tobias Drive | 4 | 2 | 0.8 | 5 | 2496.0 | Imported |
| Los Capitancillos | Along north bank of Guadalupe Creek west of Almaden Expressway | 9 | 63 | 25.5 | 0.5 | 249.6 | Local and Imported |
| McGlincey | Both sides of McGlincey Lane and north of Griffith Street | 6 | 7 | 2.8 | 6 | 2995.2 | Local and Imported |
| Oka | East bank of Los Gatos Creek north of Oka Lane extended | 4 | 17 | 6.9 | 1 | 499.2 | Local and Imported |
| Page | West of Winchester Blvd. between Hacienda Blvd. and Sunnyoaks Blvd. | 8 | 14 | 5.7 | 2 | 998.4 | Local and Imported |
| Penitencia | North of Penitencia Creek Road and west of Noble Ave. | 6 | 14 | 5.7 | 1 | 499.2 | Local and Imported |
| Sunnyoaks | West of Winchester Blvd. between Sunnyoaks Ave. and Waldo Road | 4 | 3 | 1.2 | 2 | 998.4 | Local and Imported |

e/ Estimate

## Alamitos Percolation Ponds

One offstream pond and one onstream pond receive local runoff from three sources: Alamitos Creek, Guadalupe River, and Coyote Creek by way of the Coyote-Alamitos Canal. In addition, imported water can be delivered from the Almaden Valley Pipeline by way of Guadalupe River. The onstream pond is operated during certain portions of the year by the erection of a flashboard dam on Alamitos Creek. There is no method of measuring the flow into this system except for a water stage recorder located at the flashboard dam.

During the winter, the flashboard dam is removed and a gravel dam is constructed to divert streamflow into the offstream pond. Only water of less than 25 Jackson Turbidity Units is diverted.

This area is not fenced; it is leased to the City of San Jose for development for public use.

## Budd Avenue Percolation Ponds

Three ponds in series receive local and imported water via the Upper Page Ditch and Page Pipeline. A low pressure meter measures the total combined flow to the Budd Avenue and adjacent Sunnyoaks Ponds. An overflow pipe in the most northerly Budd Avenue Pond conveys unmeasured excess flow to San Tomas Aquinas Creek through a storm drain.

Imported water can be delivered to this system without using natural stream channels, and the ponds can be operated during the winter. During periods of heavy runoff, the recharge potential of these ponds can be used to infiltrate local water.

The area is fenced and is adjacent to a subdivision.

## Camden Percolation Ponds

Local and imported water is delivered to the middle of three connected ponds via the Upper Page Ditch. The combined flow into the Camden, Page, Budd Avenue, and Sunnyoaks recharge areas is measured by a water stage recorder located at the head of the Upper Page Ditch. Flow not diverted into the Camden Ponds is measured by a water stage recorder located at Dell Avenue. An overflow pipe located in the most northerly Camden Pond returns unmeasured flow to Los Gatos Creek. Some seepage occurs along the east bank of the ponds; this seepage flows to Los Gatos Creek.

Imported water can be delivered to this system without using natural channels, and the system is operated during winter months to a limited degree without consideration of local runoff conditions. During periods of heavy runoff, however, the recharge potential of those ponds can be used to infiltrate local water.

The area is not fenced; it is leased by the Santa Clara County Parks and Recreation Department for development as a recreational facility.

## Coyote Percolation Pond

One large onstream pond is formed and regulated by the Coyote Percolation Dam, which receives local water from the Anderson-Coyote watershed via Coyote Creek and Coyote Canal, which parallels the creek. The canal is used instead of the creek to prevent high ground water conditions in areas adjacent to the creek. Water stage recorders are located both upstream and downstream of this system.

During periods of high runoff, the water level in this pond is lowered in order to prevent degradation of the infiltration rate by the spreading of turbid water.

The area is not fenced; it is a part of Coyote Park.

## Ford Road Percolation Ponds

Three onstream ponds that are formed by gravel dams, and one offstream pond receiving water from the uppermost onstream pond, receive water from Anderson Reservoir. Inflow and outflow cannot be measured.

During winter months, water levels in these ponds are lowered and gravel dams are removed to prevent turbid water from affecting recharge rates and also as a flood protection measure. Delivery cannot be made to the offstream pond if the gravel dam forming the upstream pond is not in operation.

The area is not fenced; it is a part of Coyote Park.

## Guadalupe Percolation Ponds

Three offstream ponds, and one onstream pond that is used during a portion of the year by the construction of two gravel dams in the Guadalupe River, receive local water from Almaden, Calero, or Guadalupe Reservoirs. Imported water can be delivered from the Almaden Valley Pipeline via Guadalupe River.

Two ponds are on the west side of the river and one is on the east side. Water is introduced into the southerly pond on the west side of the river by the construction of a small diversion dam near the southeast corner of the pond. A pipe is located between the two westerly ponds. Farther to the north on the Guadalupe River, a gravel dam is used to divert water to the easterly pond.

During periods of local runoff, the gravel dams are removed and turbid waters are not diverted to the offstream ponds. The area is fenced.

## Kooser Percolation Ponds

A series of four ponds receive only imported water from the Almaden Valley Pipeline. A low pressure meter measures all flows into these ponds. Weirs between the ponds are used to measure interpond flow. There is no overflow to handle surplus flows. The area is fenced.

## Los Capitancillos Percolation Ponds

A series of nine ponds receive local runoff from the Guadalupe watershed area and imported water from the Almaden Valley Pipeline. Water enters the most westerly pond from Masson Dam. This westerly pond also serves as a desilting pond and has cross levees to provide about one hour detention time. Chemicals can be introduced to decrease turbidity of the water. Some of this water returns to the Guadalupe River by way of bank seepage. All water entering the system is measured by a water stage recorder located at a Parshall flume between the uppermost pond area and the second pond. There is no measurement made of reintroduced water. At the northeasterly corner of the ninth pond, there is a pipeline that can be used to convey water to the Alamitos Pond.

Imported water can be delivered to this system without using natural channels, and the system can be operated during winter months, to a limited degree, without consideration of local runoff conditions. During periods of heavy runoff, when water in Guadalupe River is going to waste, the recharge potential of these ponds could be used to infiltrate local water.

The area is fenced. The City of San Jose and the County of Santa Clara plan to lease portions of this area to develop it for public recreational use.

McGlincey Percolation Ponds

A group of six ponds receive local and imported water by way of Kirk Canal. The flow into the ponds is measured by a water stage recorder located just north of Camden Avenue. An overflow pipe located in the most easterly pond allows excess flow to return via a storm drain to Los Gatos Creek. Some seepage also returns to Los Gatos Creek.

Imported water can be delivered to this system without using natural channels, and the system can be operated during winter months without consideration of local runoff conditions. During periods of heavy runoff, the recharge potential of these ponds can be used to infiltrate local water. The area is completely enclosed.

Oka Lane Percolation Ponds

A group of four ponds receive local and imported water by way of Kirk Ditch and Central Pipeline. Each pond has a separate connection to the Kirk Ditch, and the amount of water delivered to each pond is not measured. The most southeasterly pond is used as a desilting pond. The combined flow into the Oka and McGlincy Ponds is measured by a water stage recorder located at the head of Kirk Creek. Flow not diverted into the Oka System is measured by a water stage recorder located just north of Camden Avenue on the Kirk Ditch. Some water can be returned to Los Gatos Creek by wasteways located downstream of the Oka Ponds and above the recorder station. In addition, an overflow pipe located in the most northerly pond returns excess flows to Los Gatos Creek. Flows in the wasteway and overflow pipe are not measured. Considerable seepage occurs along the west bank of the ponds.

Imported water can be delivered to this system without using natural channels. The system can be operated during the winter months to a limited degree without consideration of local runoff conditions. During periods of heavy runoff, the recharge potential of these ponds can be used to infiltrate local water.

The area is not fenced. The Santa Clara County Parks and Recreation Department leases this area and will develop it for recreational use.

## Page Percolation Ponds

A group of eight ponds receive local and imported water by way of Page Pipeline. The combined flow into the Page Ponds, Sunnyoaks Ponds, and Budd Avenue Ponds is measured by a water stage recorder located on Upper Page Ditch at Dell Avenue. Flows not diverted to Page, Budd, or Sunnyoaks Ponds are conveyed via Page Canal past the Page Percolation System to Smith Creek, then to San Tomas Aquinas Creek. This flow is measured by a water stage recorder located at Sonuca Avenue.

Imported water can be delivered to this system without using natural channels. The system can be operated during the winter months without consideration of local runoff conditions. During periods of heavy runoff, the recharge potential of these ponds can be used to infiltrate local water. The area is fenced.

## Penitencia Percolation Ponds

A series of five ponds and a canal containing 22 check structures receive local water from Penitencia Creek during limited periods of time in the winter and spring. During the remainder of the year, imported water is placed in the ponds from the South Bay Aqueduct via the Penitencia Water Treatment Plant.

Because of the location of these ponds in relationship to the imported water system, the ponds also are operated to hold minor surges in flows. Each of the five ponds has an overflow spillway that is capable of carrying 185 cfs (5.24 cumecs) to Penitencia Creek. Water in the ponds can be released to supply irrigation and recharge demands along Sierra and Berryessa Creeks.

Flow into this system is measured by a water stage recorder located at the head of the diversion. Outflows from the ponds are not measured.

The ponds are only partially fenced; the canal is completely fenced. The City of San Jose plans to use the five ponds as a park.

## Sunnyoaks Percolation Ponds

A group of four ponds receive local and imported water via the Upper Page Ditch and by the Page Pipeline. A low pressure meter measures the total combined flow to those ponds and the Budd Avenue Ponds. There is no overflow or return flow drain from these ponds.

Imported water can be delivered to this system without using natural stream channels and can be operated during periods of high streamflow without consideration of local runoff conditions. During periods of heavy runoff, the recharge potential of these ponds can be used to infiltrate local water.

The area is fenced. The pond next to the fire station, located at the south end of the ponds, is used by the Fire Department for training purposes. There are no plans to develop this area for public use.

## Agricultural Water Use

Detailed records on amounts of ground water pumped and surface water delivered for agricultural purposes are available for the years 1966 through 1970. These records also include the net acreage to which the water is applied. The records do not indicate if the surface diversions were applied to areas also receiving ground water. For the purpose of this study, it is assumed that there is no application of both surface and ground water to the same acreage during the same six-month period.

Depths of water applied to various crops during each of the years 1967 through 1971 were determined from records of ground water pumpage and lands receiving ground water irrigation. The depths computed on the basis of net irrigated lands are shown in Table 8. Gross acres include the irrigated plot, related farm facilities, and adjacent streets. For the study area, the net irrigated lands are taken as 85 percent of the gross irrigated lands. Depths of applied water corrected to a gross acreage basis are shown in Table 9.

Depths of applied irrigation water per gross acre for the years 1962 through 1966 shown in Table 9 are based on four factors: (1) analysis of all years 1962 through 1970 to determine which years were wet, normal, or dry (based mainly on rainfall in March and April and secondly on rainfall in February); (2) determination of annual applied water for wet, normal, and dry conditions for the period 1967 through 1970; (3) assumption that applied water after 1966 was decreased for most crops due to the pump tax; and (4) calculation of unit values for the wet, normal, and dry years in the period 1962 through 1966 by adding one irrigation to values obtained from years 1967 through 1970.

## Land Use

The annual amounts of land use for the lands overlying the ground water model area are shown on Table 10, and are based on land use surveys made in 1961, 1965, and 1967 by the Department and/or Santa Clara County, and from records of the District on water use and irrigated acreage. The various types of land use are irrigated agricultural lands, urban lands, native or nonirrigated lands, and water surface areas.

The amounts of irrigated agricultural land mapped in the 1967 land use survey were greater than recorded acreage of agricultural land being supplied by wells and surface water diversions. Analysis of the discrepancy revealed that the depths of applied water obtained from the District's water use data appeared to be on the low side of a reasonable range of values. Therefore the acreage irrigated by the metered water should not be increased. Many orchards in the area are mature and can survive for a period of years without irrigation. These same orchards still have irrigation facilities and would appear to be irrigated orchard. It

TABLE 8

UNIT VALUES OF APPLIED IRRIGATION WATER: NET ACREAGE[1/]

| Crop | Calendar Year 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|
| | (Feet)[2/] | | | |
| Alfalfa | 2.05 | 2.48 | 2.09 | 2.55 |
| Apricots | 0.90 | 0.91 | 1.01 | 1.13 |
| Berries | 3.56 | 4.41 | 4.73 | 5.33 |
| Cherries | 1.13 | 1.47 | 1.31 | 1.43 |
| Corn (Sweet) | 1.72 | 1.32 | 1.79 | 1.17 |
| Flowers | 3.50 | 3.74 | 3.85 | 3.48 |
| Mixed Row Crop | 2.19 | 2.37 | 2.48 | 2.51 |
| Onions | 2.51 | 2.27 | 2.12 | 1.87 |
| Mixed Orchard | 1.10 | 1.12 | 1.06 | 1.18 |
| Pears | 1.62 | 2.13 | 1.90 | 2.00 |
| Pasture | 1.70 | 2.02 | 1.63 | 1.69 |
| Prunes | 0.94 | 1.20 | 1.10 | 1.44 |
| Tomato (Bush) | 1.81 | 1.71 | 1.72 | 1.89 |
| Walnuts | 0.94 | 1.08 | 1.17 | 1.09 |
| Vineyards | 0.33 | 0.91 | 0.72 | 0.57 |
| | (Meters)[3/] | | | |
| Alfalfa | 0.62 | 0.76 | 0.64 | 0.78 |
| Apricots | 0.27 | 0.28 | 0.31 | 0.34 |
| Berries | 1.09 | 1.34 | 1.44 | 1.62 |
| Cherries | 0.34 | 0.45 | 0.40 | 0.44 |
| Corn (Sweet) | 0.52 | 0.40 | 0.54 | 0.36 |
| Flowers | 1.07 | 1.14 | 1.17 | 1.06 |
| Mixed Row Crop | 0.67 | 0.72 | 0.76 | 0.77 |
| Onions | 0.77 | 0.69 | 0.64 | 0.57 |
| Mixed Orchard | 0.33 | 0.34 | 0.32 | 0.36 |
| Pears | 0.49 | 0.65 | 0.58 | 0.61 |
| Pasture | 0.52 | 0.62 | 0.50 | 0.52 |
| Prunes | 0.27 | 0.37 | 0.33 | 0.44 |
| Tomato (Bush) | 0.55 | 0.52 | 0.52 | 0.58 |
| Walnuts | 0.27 | 0.33 | 0.36 | 0.33 |
| Vineyards | 0.10 | 0.28 | 0.22 | 0.17 |

1/ Net acreage is irrigated portion of farm only
2/ Acre-feet per net acre.
3/ Cubic meters per net hectare.

TABLE 9

UNIT VALUE OF APPLIED IRRIGATION WATER: GROSS ACREAGE 1/

| Crop | Water Year 1961-2 | 1962-63 | 1963-4 | 1964-5 | 1965-6 | 1966-7 | 1967-8 | 1968-9 | 1969-70 |
|---|---|---|---|---|---|---|---|---|---|
| | (Feet) 2/ | | | | | | | | |
| Alfalfa | 2.75 | 2.25 | 2.75 | 2.50 | 2.75 | 1.74 | 2.10 | 1.94 | 2.17 |
| Apricots | 1.25 | 1.17 | 1.58 | 1.58 | 1.58 | 0.77 | 0.77 | 0.86 | 0.96 |
| Berries | 4.00 | 3.50 | 4.50 | 3.75 | 4.50 | 3.03 | 3.75 | 4.02 | 4.53 |
| Cherries | 1.50 | 1.33 | 1.83 | 1.83 | 1.83 | 0.96 | 1.25 | 1.11 | 1.22 |
| Corn | 2.00 | 1.75 | 2.25 | 1.92 | 2.25 | 1.46 | 1.12 | 1.52 | 0.99 |
| Flowers | 3.25 | 3.00 | 3.50 | 3.25 | 3.50 | 2.98 | 3.18 | 3.27 | 2.96 |
| Mixed Row | 2.50 | 2.17 | 2.50 | 2.00 | 2.25 | 1.86 | 2.01 | 2.10 | 2.13 |
| Mixed Orchard | 1.33 | 1.25 | 1.58 | 1.58 | 1.58 | 0.94 | 0.95 | 0.90 | 1.00 |
| Onions | 2.25 | 1.17 | 1.67 | 1.67 | 1.67 | 2.13 | 1.92 | 1.80 | 1.59 |
| Pears | 2.00 | 1.75 | 2.33 | 2.33 | 2.33 | 1.38 | 1.81 | 1.62 | 1.70 |
| Pasture | 2.25 | 1.75 | 2.58 | 2.33 | 2.58 | 1.45 | 1.72 | 1.39 | 1.44 |
| Prunes | 1.33 | 1.17 | 1.67 | 1.67 | 1.67 | 0.80 | 1.02 | 0.94 | 1.22 |
| Tomatoes | 2.00 | 1.75 | 2.25 | 1.92 | 2.25 | 1.54 | 1.45 | 1.46 | 1.61 |
| Walnuts | 1.25 | 1.17 | 1.58 | 1.58 | 1.58 | 0.80 | 0.92 | 0.99 | 0.93 |
| Vineyard | 0.67 | 0.33 | 0.84 | 0.67 | 0.84 | 0.28 | 0.77 | 0.61 | 0.48 |
| | (Meters) 3/ | | | | | | | | |
| Alfalfa | 0.84 | 0.69 | 0.84 | 0.76 | 0.84 | 0.53 | 0.64 | 0.59 | 0.66 |
| Apricots | 0.38 | 0.36 | 0.48 | 0.48 | 0.48 | 0.23 | 0.23 | 0.26 | 0.29 |
| Berries | 1.22 | 1.07 | 1.37 | 1.14 | 1.37 | 0.92 | 1.14 | 1.23 | 1.38 |
| Cherries | 0.46 | 0.41 | 0.56 | 0.56 | 0.56 | 0.24 | 0.38 | 0.34 | 0.37 |
| Corn | 0.61 | 0.53 | 0.69 | 0.59 | 0.69 | 0.46 | 0.34 | 0.46 | 0.30 |
| Flowers | 0.99 | 0.91 | 1.07 | 0.99 | 1.07 | 0.91 | 0.97 | 1.00 | 0.90 |
| Mixed Row | 0.76 | 0.66 | 0.76 | 0.61 | 0.69 | 0.57 | 0.61 | 0.64 | 0.65 |
| Mixed Orchard | 0.41 | 0.38 | 0.48 | 0.48 | 0.48 | 0.29 | 0.29 | 0.27 | 0.30 |
| Onions | 0.76 | 0.36 | 0.51 | 0.51 | 0.51 | 0.65 | 0.59 | 0.55 | 0.48 |
| Pears | 0.61 | 0.53 | 0.71 | 0.71 | 0.71 | 0.42 | 0.55 | 0.49 | 0.52 |
| Pasture | 0.76 | 0.53 | 0.79 | 0.71 | 0.79 | 0.44 | 0.52 | 0.42 | 0.44 |
| Prunes | 0.41 | 0.36 | 0.51 | 0.51 | 0.51 | 0.24 | 0.31 | 0.29 | 0.37 |
| Tomatoes | 0.61 | 0.53 | 0.76 | 0.59 | 0.76 | 0.47 | 0.44 | 0.45 | 0.49 |
| Walnuts | 0.38 | 0.36 | 0.48 | 0.48 | 0.48 | 0.24 | 0.28 | 0.30 | 0.28 |
| Vineyard | 0.20 | 0.10 | 0.26 | 0.20 | 0.26 | 0.09 | 0.23 | 0.19 | 0.15 |

1/ Gross acreage includes irrigated and nonirrigated portions of farm.
2/ Acre-feet per gross acre.
3/ Cubic meters per gross hectare.

TABLE 10

LAND USE

| Year | Irrigated Agriculture | Dry Farm | Total Agriculture and Native | Urban | Water Surface |
|---|---|---|---|---|---|
| | | | (Acres) | | |
| 1962 | 62,440 | 17,770 | 79,210 | 77,130 | 19,960 |
| 1963 | 58,070 | 18,420 | 76,490 | 80,850 | 19,960 |
| 1964 | 53,720 | 19,080 | 72,800 | 84,540 | 19,960 |
| 1965 | | | 68,970 | 88,220 | 20,110 |
| 1966 | | | 66,890 | 90,300 | 20,110 |
| 1967 | | | 64,550 | 92,640 | 20,110 |
| 1968 | | | 61,540 | 95,650 | 20,110 |
| 1969 | | | 59,080 | 98,450 | 19,770 |
| 1970 | | | 56,640 | 101,220 | 19,440 |
| | | | (Hectares) | | |
| 1962 | 25,270 | 7,160 | 32,430 | 31,210 | 8,080 |
| 1963 | 23,500 | 7,450 | 30,950 | 32,720 | 8,080 |
| 1964 | 21,740 | 7,720 | 29,460 | 34,210 | 8,080 |
| 1965 | | | 27,910 | 35,700 | 8,140 |
| 1966 | | | 27,070 | 36,540 | 8,140 |
| 1967 | | | 26,120 | 37,500 | 8,140 |
| 1968 | | | 24,910 | 38,710 | 8,140 |
| 1969 | | | 23,910 | 39,840 | 7,870 |
| 1970 | | | 22,920 | 40,960 | 7,790 |

was concluded that some of the agricultural lands mapped as irrigated in the 1967 land use survey were probably nonirrigated. One of the major factors affecting irrigation of agricultural lands was the imposition of a pump tax in the mid-1960's. For this study, it was assumed that the irrigated agricultural land use data in Table 10 is reliable for years 1961 through 1964 and can be used as a basis to determine agricultural applied water. Because the amount of irrigated land from 1965 on probably contains significant amounts of underirrigated or nonirrigated orchard and pasture lands, the acreage of irrigated and nonirrigated lands have been combined with native lands in Table 10. Changes in land use from 1967 through 1970 are based on data on lands subdivided during each year. General land use is shown on Figure 12.

## Ground Water Pumpage

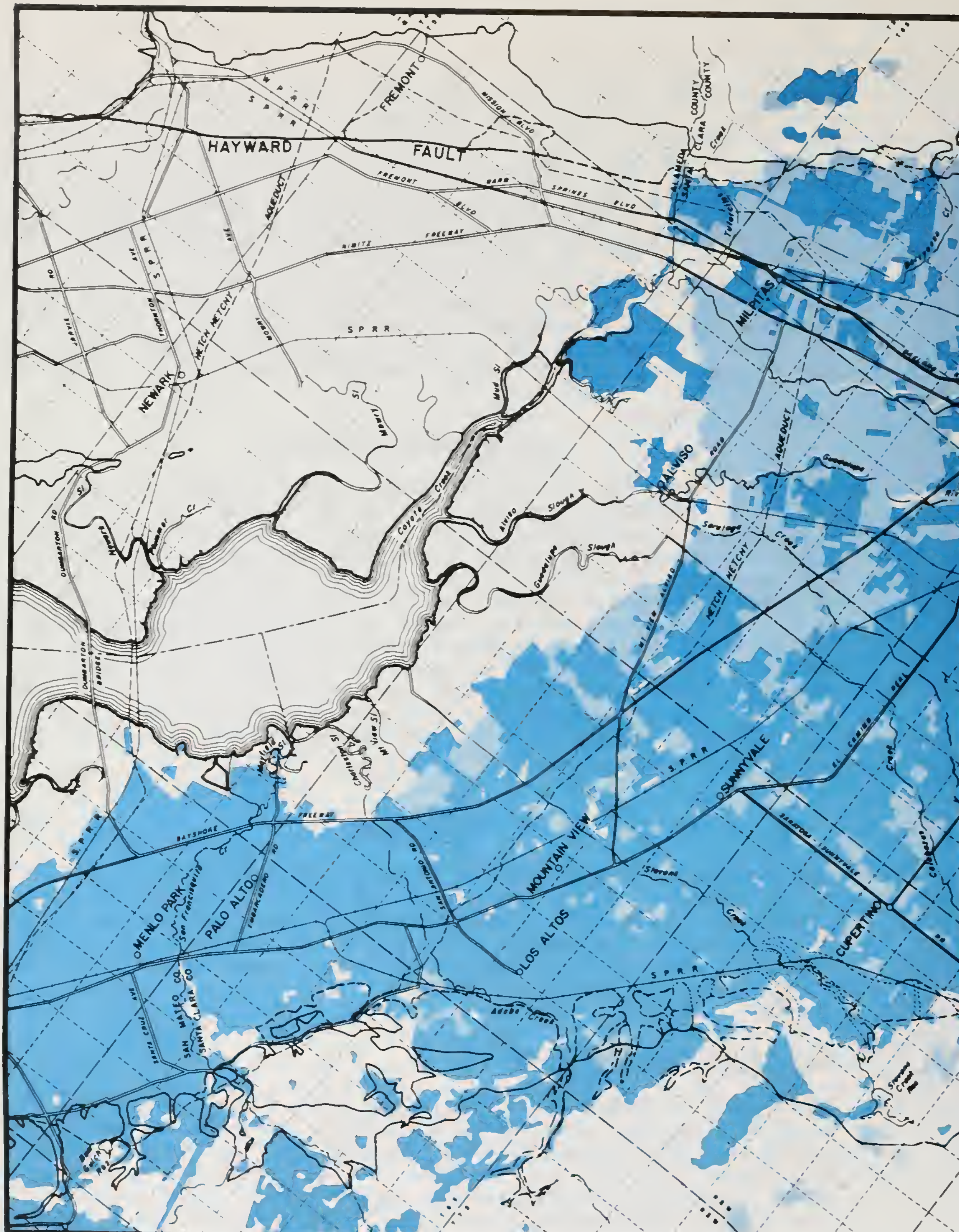
The annual amounts of ground water pumped during the study period are shown on Table 11. Water pumped by private and public utilities is based on metered flows. Water produced by individual domestic and industrial wells has been metered from 1964 to date, and was assumed to be constant for 1962 through 1964. The amounts of irrigation water pumped during 1962-63 and 1963-64 were computed as the difference between demand (irrigated acreage multiplied by depth of applied water) and surface water diversions. From 1966 on, the actual metered pumpage was used. The first fill year of metering was 1965, and may not include all agricultural pumpage. To compensate for possible missing data in 1965, the agricultural pumpage for 1965 was taken as the greater of 1965 and 1966 pumpage in each nodal area.

## Water Quality

The variety of uses to which a water resource may be put is limited by the quality of that resource. Water suitable for irrigation of crops, for example, may contain certain elements which make it undesirable for use as drinking water and vice versa. The quality of the surface and ground water resource of North Santa Clara Valley is described below.

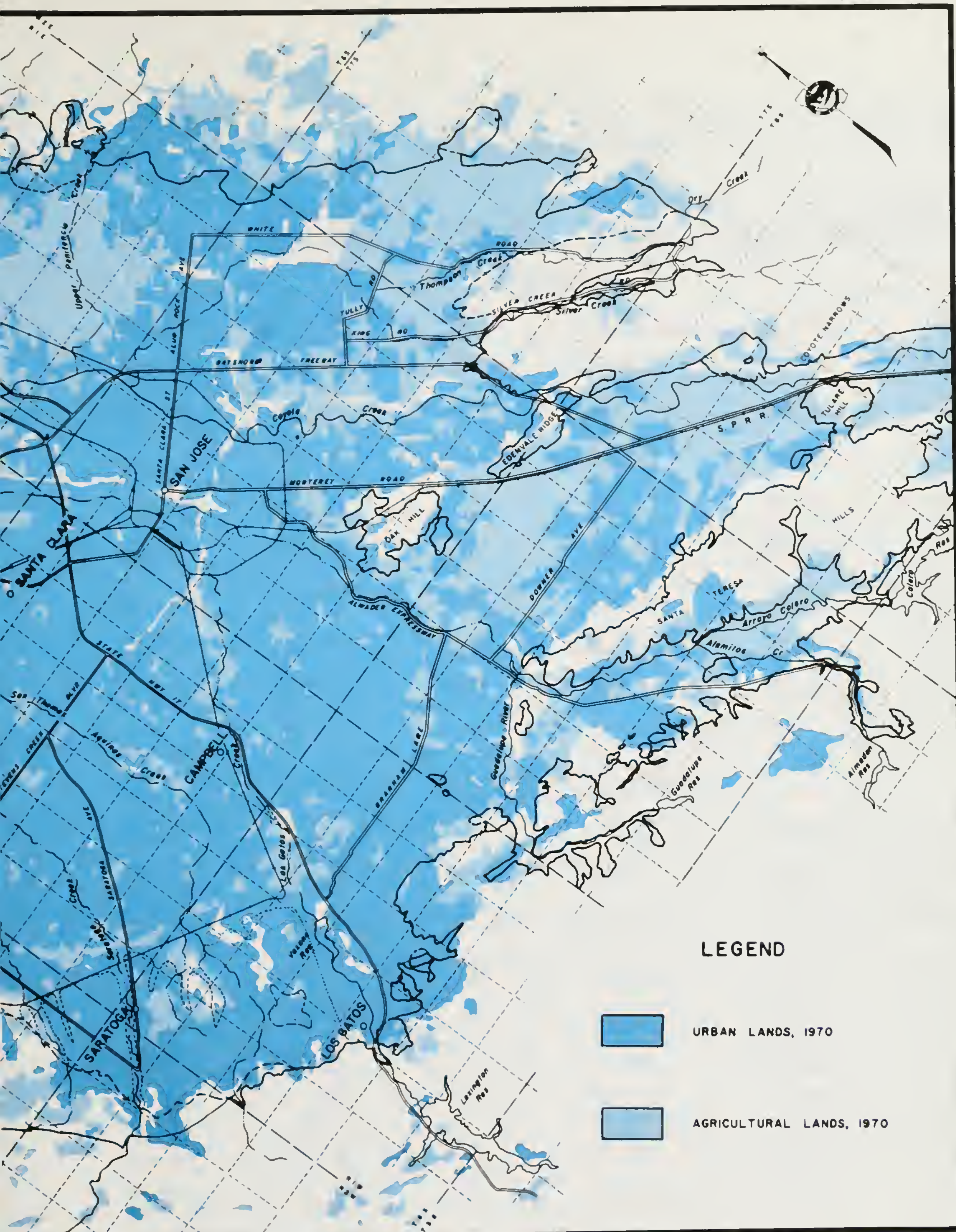
### Quality of Surface Water

Local surface water in North Santa Clara Valley is mostly of excellent quality, highly suitable for agricultural and domestic purposes. In some areas, the hardness is considered excessive at times, but tends toward lower overall averages by mixing in reservoir. Poor quality water occurs in the lower reaches of the tidal inlet channels due to incursion of saline water from




LAND USE 1970

FIGURE 12




# SANTA CLARA VALLEY

TABLE 11

GROUND WATER PUMPAGE

| Calendar Year | Agriculture | Municipal | Domestic | Individual Industries | Total |
|---|---|---|---|---|---|
| | | | (Acre-Feet) | | |
| 1962 | 91,710 | 70,320 | 760 | 19,460 | 182,250 |
| 1963 | 74,680 | 67,230 | 750 | 19,460 | 162,120 |
| 1964 | 94,090 | 82,830 | 750 | 19,460 | 197,130 |
| 1965 | 53,980 | 76,020 | 510 | 18,380 | 148,890 |
| 1966 | 41,110 | 87,820 | 890 | 23,010 | 152,830 |
| 1967 | 23,790 | 79,940 | 1,110 | 22,080 | 126,920 |
| 1968 | 32,830 | 113,820 | 1,090 | 23,480 | 171,220 |
| 1969 | 27,740 | 100,870 | 950 | 22,660 | 152,220 |
| 1970 | 27,010 | 97,670 | 950 | 22,660 | 148,290 |
| | | | (Cubic Hectometers)1/ | | |
| 1962 | 113.12 | 86.74 | 0.94 | 24.00 | 224.80 |
| 1963 | 92.12 | 82.93 | 0.93 | 24.00 | 199.98 |
| 1964 | 116.06 | 102.17 | 0.93 | 24.00 | 243.16 |
| 1965 | 66.58 | 93.77 | 0.63 | 22.67 | 183.65 |
| 1966 | 50.71 | 108.33 | 1.10 | 28.38 | 188.52 |
| 1967 | 29.34 | 98.61 | 1.37 | 27.24 | 156.56 |
| 1968 | 40.50 | 140.40 | 1.34 | 28.96 | 211.20 |
| 1969 | 34.22 | 124.42 | 1.17 | 27.95 | 187.76 |
| 1970 | 33.32 | 120.48 | 1.17 | 27.95 | 182.92 |

1/ Million cubic meters

the Bay, and abnormally high boron concentrations have occurred in Penitencia Creek. Other than in these instances, there does not appear to be any generally consistent and substantial quality variation in surface waters of the area.

The total dissolved solids (TDS) content of the water ranges from about 200 to 400 milligrams per liter (mg/l), while its chemical character is calcium-magnesium bicarbonate. However, while neither consistent nor substantial, the upper range of TDS content in streams on the western side of the valley tend to be about 100 mg/l higher than those on the eastern side. This may be a reflection of geologic conditions on the western side which form the watersheds for these streams. There also is another geologically derived water quality condition which must be noted, even though it does not constitute a direct problem except when associated with the biological food chain which includes edible game fish.

In 1970, evidence of mercury from abandoned mercury mines was found in some surface water in Santa Clara Valley. Samples of water collected from Alamitos Creek were determined to contain mercury concentrations generally in the order of 0.5 micrograms per liter (μg/l), which is well below the Environmental Protection Agency tentative mercury concentration limit of 2.0 μg/l for public drinking water supplies. Subsequently, samples of fish were collected from Almaden and Calero Reservoirs which receive water from Alamitos Creek. Analysis of fish flesh samples showed mercury concentrations greater than 0.5 micrograms per gram (μg/g) which is 1,000 times greater than the concentrations generally found in the water. The maximum acceptable limit of mercury concentrations in fish flesh, as established by the U. S. Food and Drug Administration (Sport Fishing Institute, 1973), is 0.5 μg/g. As a result of the findings, signs warning of mercury contamination were posted at Calero and Almaden Reservoirs, and mercury analyses of water, sediment, and fish flesh samples collected from other surface waters in Santa Clara County were made by several agencies. The wide interest by state and federal agencies in this problem was spurred by the fact that it presented one of the few, if not the only, opportunities for a case study of mercury contamination of fish in inland waters not associated with industrial pollution. Development of procedures for biological sample preparation, as well as analytical techniques in the micro-concentration range, were of major interest to some agencies, while finding a solution to the physical problem and making management decisions regarding it was the priority interest of other agencies. Some of the results of these studies are included below in the discussion of Calero, Lexington, and Anderson Reservoirs, each of which impounds water that flows into the area of investigation from watersheds with differing geochemical characteristics.

Calero Reservoir. In four samples of water collected from this reservoir in 1971, TDS ranged from 180 to 290 mg/l and the water was hard to very hard (160 to 320 mg/l as $CaCO_3$). Mercury concentration in the flesh of a largemouth bass (*Micropterus salmoides*) collected from the reservoir in April 1971 was 5.1 μg/g, which is above the acceptable limit of 0.5 μg/g. Most of the other fish flesh analyzed also exceeded this limit. Warnings of mercury contamination were posted at the reservoir.

Lexington Reservoir. This reservoir on Los Gatos Creek, which is geochemically similar to Alamitos Creek, also was sampled four times in 1971. TDS varied from 170 to 360 mg/l and total hardness from 160 to 310 mg/l. In 1971 and 1972, mercury was detected in the tissue of nearly all fish sampled. About 40 percent of the tissue samples exceeded the mercury concentration limit of 0.5 μg/g, with the highest concentration of mercury being 0.9 μg/g.

Anderson Reservoir. This reservoir impounds Coyote Creek water derived from a geochemical province quite different from the foregoing two. The reservoir was sampled four times in 1971, showing TDS from 200 to 230 mg/l and hard water 160 to 180 mg/l as $CaCO_3$). Mercury concentrations in fish flesh were below the acceptable limit of 0.5 μg/g.

## Quality of Imported Water

The quality of water imported from the Sacramento-San Joaquin Delta is influenced by climatic conditions, irrigation return flow, municipal and industrial waste discharges, and tidal inflow from the Bay. There is a marked seasonal variation. TDS, for example, range from less than 200 mg/l in spring and early summer to more than 400 mg/l in fall and winter. There is also a seasonal change in the predominant ions. For example, in December 1968 chloride was the predominant anion; in August 1969 bicarbonate predominated. Typically, the sodium content ranges from about 30 to 60 percent.

Water imported by the City of San Francisco and served in the Santa Clara Valley is a mixture from two sources: the Hetch Hetchy Project on the upper Tuolumne River and surface water from Alameda and Santa Clara Counties. Both water types are of calcium-bicarbonate character, but the TDS of Hetch Hetchy water is about 30 mg/l, and that of Alameda County water ranges from 150 to 450 mg/l. Based upon the usual proportions of these sources served in the Santa Clara Valley, the average of the delivered water from the City of San Francisco is about 60 mg/l of TDS.

## Quality of Ground Water

Ground water in most of the major producing aquifers, although hard, is of good to excellent mineral quality and suitable for most uses. It is generally bicarbonate in type, with sodium and calcium the predominant cations. TDS in most ground water ranges from about 300 to 600 mg/l. Ground water of inferior quality occurs in the saline water intrusion zone, in formations containing connate water, and in the Penitencia Creek alluvial fan.

The saline water intrusion zone extends inland from the Bay to approximately the Bayshore and Nimitz Freeways. Generally, shallow aquifers, those less than 100 feet (30 meters) deep and adjacent to tidal inlet streams, have been affected. Some degradation of deeper aquifers also has occurred, probably by interchange of water between the upper and lower aquifers through improperly constructed or abandoned wells. At some locations, chloride concentrations in the shallow aquifers exceed 1,000 mg/l. With properly constructed wells, ground water of good quality can be obtained from the deeper aquifers, and that of satisfactory quality from the shallow aquifers in a considerable portion of the area near the Bay.

Formations which yield connate water are the marine deposits of Cretaceous and Tertiary Age. These underlie the fresh ground water body in much of the valley floor area. The Evergreen area is one in which connate water with chloride exceeding 1,000 mg/l has been found at normal production depths of between 300 and 800 feet (100 to 240 meters). This saline water is under artesian head with the potentiometric surface at about the same elevation as the overlying fresh water aquifer. There is also evidence of connate water-bearing deposits at other locations in the valley at depths from about 500 to 1,000 feet (150 to 300 meters).

Ground water containing boron in excess of 1 mg/l has been found in the Penitencia Creek alluvial fan. At least part of this boron can be attributed to the recharge of water from Penitencia Creek which often contains high boron concentrations in excess of 1 mg/l. Although a maximum of 0.5 mg/l is recommended for irrigation, this ground water has been used for agricultural and domestic purposes with no apparent adverse effects.

## Minor Elements

A study of minor elements in water of the Santa Clara Valley was conducted by Averett and others (1971). Samples were collected from wells, springs, streams, reservoirs, and imported water. Spectrographic analyses showed wide ranges in concentration of some minor elements, especially aluminum (.0014 to 1.875 mg/l), iron (.0025 to 1.6 mg/l), manganese (.0014 to 3.23 mg/l), and zinc (.0057 to 3.0 mg/l). Wide variations occurred both within a given sampling station and between different sampling stations. This is not uncommon with minor elements in these concentration ranges and under the heterogeneous environmental conditions which exist in the area. These wide variations can be attributed to a combination of factors including ground and surface water hydrolog geologic variations, effects of well casings and screens, and sampling and analytical procedures. Because of these uncertainties, the report stated that the results must be used with caution

Data from the comprehensive study by the Geological Survey confirm the general ranges of concentration of minor elements which have been detected in occasional samplings of ground and surface waters by the Department of Water Resources in the area during the past 10 to 15 years. In general, the observed concentrations of minor elements in these waters would not be considered to constitute water quality problems. However, the high values in the ranges of iron and manganese are excessive for domestic water, and those of zinc and manganese would not be recommended for continuous use on agricultural soils.

## Consumptive Use and Recharge of Rain and Delivered Water

A basic part of a water inventory is the development of annual values for the depth of consumptive use and recharge of rain and delivered water applied to various land use classes within norther Santa Clara County. Consumptive use is defined as the amount of water used by the vegetative growth of a given area in transpiration, building of plant tissue, and evaporated from adjacent soil. It also includes the water evaporated in industrial process household use, or permanently incorporated in a product. Delivere water is that delivered by man-made works to a given land use. A portion of the rainfall on the alluvial surfaces becomes consump tive use or recharge. The remaining is runoff out of the area.

A computerized method of determining the disposition of precipitation and delivered water applied to irrigated lands was used in this study. The method compared the available moisture against the demand for water in the root zone on a monthly basis during the winter season and as a lump sum for the growing season.

## Evaporation

The first demand on available moisture is evaporation. Daily evaporation data are available from Weather Bureau evaporation stations in the study area for years since 1960. The measured evaporation pan rates have been corrected to water surface evaporation rates by use of monthly pan evaporation constants.

From the evaporation record, average rates of evaporation are determined for each month of each year for storm periods and nonstorm periods. Daily evaporation rates are shown on Table 12.

Evaporation from individual storms on the valley floor is computed in the following manner.

1. An individual storm is considered to be a period of rainfall that is separated from another by at least two days of zero precipitation.

2. The daily rate of evaporation from all surfaces during and after storm periods is assumed equal to the average daily pan rate during like periods.

3. On pervious areas, the evaporation computation consisted of two parts: (1) during storm periods, the evaporation is computed using the daily evaporation rates shown on Table 12 for storm periods for the number of days in which precipitation occurred; and (2) after storm periods, the evaporation is computed using the after-storm rate, up to a total of 0.060 inch (1.53 mm), if available, or until another storm occurred. The sum of the two parts is the total evaporation for an individual storm from pervious areas. The 0.060 inch (1.53 mm) maximum is based on data published in State Division of Water Resources Bulletin No. 33, which notes that the average evaporation loss from the topsoil is one-half acre-inch per acre (17.7 cm) after each rainstorm, although the total evaporation after a storm may amount to 0.070 inch (1.77 mm).

4. On impervious areas, the evaporation is computed using the daily evaporation rate for storm periods for the number of days in which precipitation occurred; and (2) after storm periods, the evaporation is computed using the after-storm rate until the sum of the two parts amounts to a maximum of 0.050 inch (1.27 mm) or until another storm occurs. The maximum of 0.050 inch (1.27 mm) is exceeded only when the storm period is sufficiently long so that the evaporation during the storm exceeds 0.050 inch (1.27 mm). In such instances the evaporation after storms is considered to be zero.

5. When the evaporation rate exceeds the daily precipitation, the amount of the latter is taken as the daily evaporation.

TABLE 12

AVERAGE DAILY EVAPORATION RATES

| Month | During Storm | Non-Storm | Month | During Storm | Non-Storm |
|---|---|---|---|---|---|
| | | (Inches) | | | |
| October | 0.023 | 0.598 | April | 0.067 | 0.154 |
| November | 0.026 | 0.031 | May | 0.052 | 0.175 |
| December | 0.014 | 0.015 | June | 0.053 | 0.207 |
| January | 0.027 | 0.026 | July | 0.043 | 0.180 |
| February | 0.045 | 0.068 | August | 0.043 | 0.163 |
| March | 0.057 | 0.102 | September | 0.043 | 0.134 |
| | | (Millimeters) | | | |
| October | 0.59 | 1.51 | April | 1.70 | 3.91 |
| November | 0.66 | 0.79 | May | 1.32 | 4.45 |
| December | 0.35 | 0.38 | June | 1.35 | 5.25 |
| January | 0.94 | 0.66 | July | 1.09 | 4.55 |
| February | 1.14 | 1.73 | August | 1.09 | 4.15 |
| March | 1.45 | 2.59 | September | 1.09 | 3.40 |

## Evapotranspiration

The potential amounts of moisture that can become evapotranspiration are affected by both climatic and plant factors. Monthly evapotranspiration rates for various crops have been determined for the Central Valley area and published in DWR Bulletin No. 113-2, "Vegetative Water Use", August 1967. The values in the bulletin were modified for use in the Santa Clara area by applying the ratios of the mean temperatures and the percentage of daylight hours for the two areas. The resulting evapotranspiration values for the Santa Clara area are presented in Table 13.

TABLE 13

AGRICULTURAL WATER USE FACTORS

Monthly Evapotranspiration

| Month | Improved Pasture* (in.) | Improved Pasture* (cm) | Alfalfa (in.) | Alfalfa (cm) | Sugar Beets (in.) | Sugar Beets (cm) | Deciduous Orchard (in.) | Deciduous Orchard (cm) | Rice (in.) | Rice (cm) | Nonirrigated Barley (in.) | Nonirrigated Barley (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| October | 3.5 | *8.89* | 3.5 | *8.89* | 3.5 | *8.89* | 2.7 | *6.86* | 3.2 | *8.13* | 2.0 | *5.08* |
| November | 1.7 | *4.32* | 1.7 | *4.32* | 1.7 | *4.32* | 1.1 | *2.79* | 1.5 | *3.81* | 1.7 | *4.32* |
| December | 0.9 | *2.28* | 0.9 | *2.28* | 0.9 | *2.28* | 0.9 | *2.28* | 0.9 | *2.28* | 0.9 | *2.28* |
| January | 1.1 | *2.79* | 1.1 | *2.79* | 1.0 | *2.54* | 1.1 | *2.79* | 0.9 | *2.28* | 1.1 | *2.79* |
| February | 1.9 | *4.83* | 1.9 | *4.83* | 1.3 | *3.30* | 1.4 | *3.56* | 1.6 | *4.06* | 1.9 | *4.83* |
| March | 3.1 | *7.87* | 2.9 | *7.37* | -- | -- | 2.1 | *5.33* | 1.4 | *3.56* | 3.1 | *7.87* |
| April | 4.6 | *11.68* | 4.1 | *10.41* | -- | -- | 3.2 | *8.13* | 4.3 | *10.92* | 3.4 | *8.64* |
| May | 5.7 | *14.48* | 5.1 | *12.95* | 1.7 | *4.32* | 4.6 | *11.68* | 7.1 | *18.03* | 1.2 | *3.05* |
| June | 7.3 | *18.54* | 6.5 | *16.51* | 5.6 | *14.22* | 6.2 | *15.75* | 8.9 | *22.61* | 0.4 | *1.02* |
| July | 7.4 | *18.80* | 6.8 | *17.27* | 7.7 | *19.56* | 6.8 | *17.27* | 9.0 | *22.86* | 0.0 | *0.00* |
| August | 6.5 | *16.51* | 6.2 | *15.75* | 6.6 | *16.76* | 5.8 | *14.73* | 7.7 | *19.56* | 0.0 | *0.00* |
| September | 4.9 | *12.45* | 4.8 | *12.19* | 5.3 | *13.46* | 4.3 | *10.92* | 6.1 | *15.49* | 0.3 | *0.76* |

*Improved pasture considered equivalent to potential evapotranspiration.

AVAILABLE WATER-HOLDING CAPACITY OF SOILS[1/]

| Soil Type | Cubic inches per foot of depth | Cubic centimeters per meter of depth | Soil Type | Cubic inches per foot of depth | Cubic centimeters per meter of depth |
|---|---|---|---|---|---|
| Sand | 1.0 | *578.9* | Silty Clay | 1.7 | *984.1* |
| Clay | 1.0-1.5 | *578.9-868.4* | Silty Clay Loam | 2.0 | *1157.8* |
| Clay Loam | 1.4 | *810.5* | Silt Loam | 2.3 | *1331.5* |
| Loam | 1.7 | *984.1* | Silt | 2.9 | *1678.8* |

1/ H. Schulbach, in "Soil and Water", University of California, Agricultural Extension, Winter 1971.

EFFECTIVE ROOTING DEPTH

| Irrigated Crop | Effective Root Depth (in.) | Effective Root Depth (cm) | Irrigated Crop | Effective Root Depth (in.) | Effective Root Depth (cm) |
|---|---|---|---|---|---|
| Pasture | 24 | *61* | Misc. Truck | 36 | *91* |
| Alfalfa | 72 | *183* | Tomatoes | 60 | *152* |
| Sugar Beets | 60 | *152* | Orchard, Mixed | 72 | *183* |
| General Field | 48 | *122* | Vineyard | 60 | *152* |
| Walnuts | 96 | *244* | | | |

## Soil Moisture and Effective Root Depth

Soil texture influences the rate of evapotranspiration through its effect on the available water-holding capacity (AWC) of the soil. AWC is defined as the capacity of a soil to retain water that can be readily absorbed by plant roots. It is considered to be water held in the soil against a pressure of 15 bars and is expressed as a percentage of the oven-dry weight of a soil. AWC also can be thought of as the difference between the field capacity and permanent wilting point of a soil.

The effective root depth of crops is variable and is affected by soil depth, moisture penetration, and plant rooting characteristics. Table 13 presents data developed by this Department and by the University of California Agricultural Extension on AWC and rooting depth used in the Santa Clara area. than coarse coarse-textured soils.

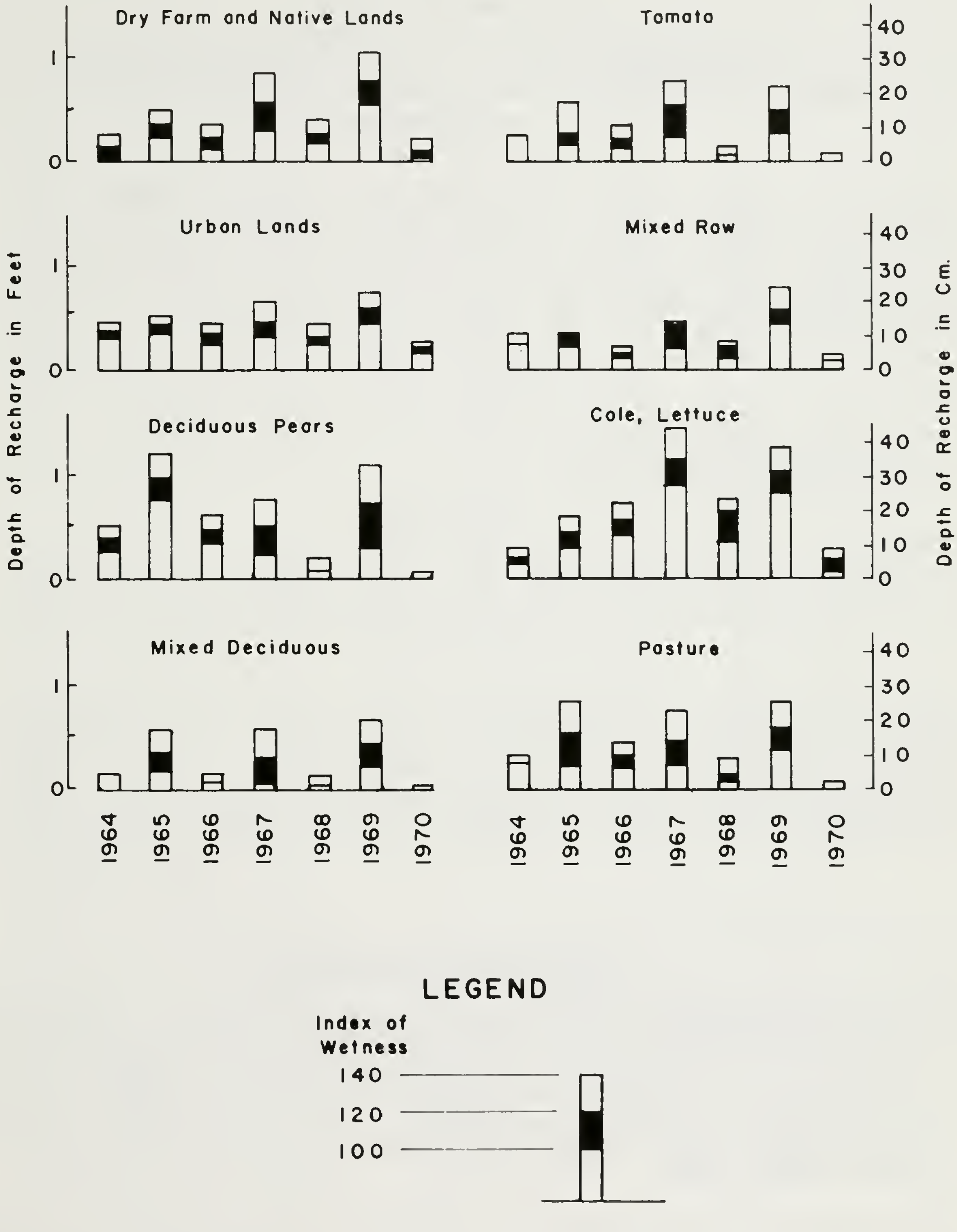
## Direct Recharge from Rain and Applied Water

The depth of rain and applied water which becomes recharge was computed for various groups of crop areas. The crops were grouped as follows:

| Group | Crops |
|---|---|
| 1 | Pears |
| 2 | Other deciduous fruit and nut |
| 3 | Tomato, sugar beets, asparagus, melons |
| 4 | Beans, carrots, peppers, mixed row, and other truck crops |
| 5 | Onions, cole, corn, lettuce, potato |
| 6 | Flowers, berries |
| 7 | Pasture, alfalfa, lawn |
| 8 | Vineyards |
| 9 | Nonirrigated deciduous fruit and nut |
| 10 | Urban |
| 11 | Native |

The resulting depths of recharge by the relative wetness of the above groups are shown on Figure 13. The values for the irrigated agricultural groups are combined to obtain the depths of recharge for each node for each year of the study period. The basis for combining values is the crop distribution existing within each node during 1957, which is assumed to exist during the entire study period. For urban areas, the average depth of applied water was assumed to be 3 feet (1 m). The depth of recharge for urban areas and for dry farm or native areas is shown on Figure 13.

Annual amounts of recharge from the combination of rain and applied water was computed for each node as the product of the depth of recharge (in feet) and the area of land use (in acres). The total amount of direct recharge from rain and applied water for the ground water basin is listed in the basin inventory in Table 14.




DEPTH OF RECHARGE FROM RAIN AND APPLIED WATER

TABLE 14

GROUND WATER BASIN INVENTORY

| | Recharge | | | | | Pumpage | | | | | Net |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Direct | Stream and Pond | Over-land | Compac-tion | Total | Agri-culture | Water Company | Dom-estic | Indust-rial | Total | |
| | | | | | (thousand acre-feet) | | | | | | |
| 62-63 | 91.1 | 118.3 | 8.2 | 20.6 | 238.2 | 74.7 | 67.3 | 0.8 | 19.5 | 162.1 | 76.1 |
| 63-64 | 54.9 | 62.9 | 5.9 | 20.0 | 143.6 | 94.1 | 82.8 | 0.8 | 19.5 | 197.2 | -53.6 |
| 64-65 | 68.1 | 116.3 | 6.2 | 20.0 | 210.6 | 54.0 | 76.0 | 0.5 | 18.4 | 148.9 | 61.7 |
| 65-66 | 49.2 | 80.5 | 5.4 | 20.0 | 155.1 | 41.1 | 87.8 | 0.9 | 23.0 | 152.8 | 2.3 |
| 66-67 | 73.7 | 131.4 | 6.8 | 20.0 | 231.9 | 28.8 | 79.9 | 1.1 | 22.1 | 131.9 | 100.0 |
| 67-68 | 44.9 | 125.0 | 6.2 | 10.9 | 187.0 | 32.8 | 113.8 | 1.1 | 23.5 | 171.2 | 15.8 |
| 68-69 | 95.2 | 124.8 | 6.9 | 0.0 | 226.9 | 27.7 | 100.9 | 0.9 | 22.7 | 152.2 | 74.7 |
| 69-70 | 47.6 | 146.5 | 6.9 | 0.0 | 201.0 | 27.7 | 97.7 | 0.9 | 22.7 | 148.3 | 52.7 |
| | | | | | (cubic hectometers) | | | | | | |
| 62-63 | 112.4 | 145.9 | 10.1 | 25.4 | 293.8 | 92.1 | 83.0 | 0.9 | 24.1 | 200.1 | 93.7 |
| 63-64 | 67.7 | 77.6 | 7.3 | 24.7 | 177.3 | 116.1 | 102.1 | 0.9 | 24.1 | 243.2 | -65.9 |
| 64-65 | 84.0 | 143.5 | 7.6 | 24.7 | 259.8 | 66.6 | 93.7 | 0.6 | 22.7 | 183.6 | 76.2 |
| 65-66 | 60.7 | 99.3 | 6.6 | 24.7 | 191.3 | 50.7 | 108.3 | 1.1 | 28.4 | 188.5 | 2.8 |
| 66-67 | 90.9 | 162.1 | 8.4 | 24.7 | 286.1 | 35.5 | 98.6 | 1.4 | 27.3 | 162.8 | 123.3 |
| 67-68 | 55.4 | 154.2 | 7.6 | 13.4 | 230.6 | 40.5 | 140.4 | 1.4 | 29.0 | 211.3 | 19.3 |
| 68-69 | 117.4 | 153.9 | 8.5 | 0.0 | 279.8 | 34.2 | 124.5 | 1.1 | 28.0 | 187.8 | 92.0 |
| 69-70 | 58.7 | 180.7 | 8.5 | 0.0 | 247.9 | 34.2 | 120.5 | 1.1 | 28.0 | 183.8 | 64.1 |

## Stream and Pond Recharge

In the study area, reservoirs in the tributary hill areas store runoff for later release to permeable valley areas for recharge. In addition, a portion of the imported water is delivered to ponds for recharge. The flow in streams on the valley floor is computed by estimating streamflow tributary to the ground water area (see Table 5) and adding local runoff from drainage areas within the ground water area.

The method used to estimate recharge of streamflow and imported water percolating in stream channels and percolation pond areas is described in following paragraphs. In addition to recharge in streams and ponds, some of the local runoff infiltrates on its overland path from the area where direct recharge occurs to the main channels. Based on detailed analysis in Alameda County by the Department of Water Resources (1973), 30 percent of the rain and applied water remaining (after deductions for direct recharge and evapotranspiration) was estimated to be recharge during overland flow. The annual amounts are listed as part of the basin inventory in Table 14.

Recharge was estimated for each node using information on the type and size of drainage channels shown on Figure 14, analysis of flow duration and percolation rate data in District files, and where possible, was checked for aggregations of nodes by use of stream gages up and downstream from such aggregations. Stream recharge was apportioned to a node in terms of the area of the stream reach contained within the node, the estimated percolation rate for the reach, and the flow duration.

Nodal Percolation (Ac-Ft) = Stream Area within Node (Ac) x Perc. Rate (Ac-Ft/Ac/Day) x Flow Duration (Days)

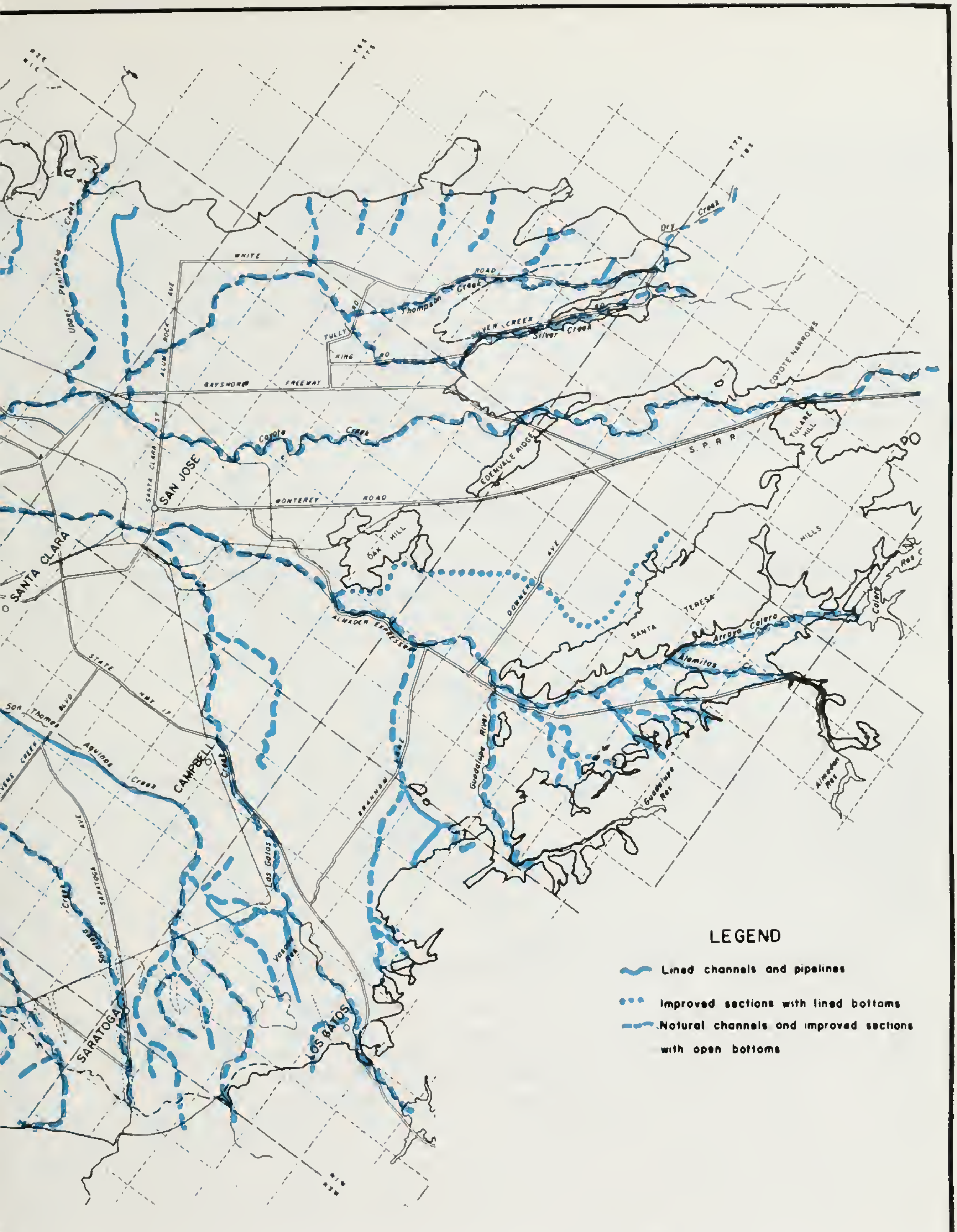
Subject to the condition that the streamflow rate is greater than or equal to the percolation rate, if the streamflow rate is less than the percolation rate, then the percolation rate was assumed to be equal to streamflow rate.

For streams on the west side of the valley, percolation rates were estimated on the basis of gaged data at upstream and downstream locations and estimates of local inflow between the two gaging stations. For streams that do not have gaging stations, nodal percolation rates were based on corresponding values at neighboring nodes, and flow durations were based on gaging stations having drainage area characteristics similar to the area under consideration.

For streams on the east side of the valley, the percolation was obtained as a difference between estimated runoff from the hills and estimated flows reaching the major creeks. Most of smaller streams on the east side do not have well defined channels; the runoff from these streams is mostly spread over the valley floor and is infiltrated, except during periods of heavy rainfall when some runoff would reach the major creeks.

Total recharge in the streams and ponds is the sum of natural recharge and recharge of imported water. These amounts are listed in the basin inventory in Table 14.


DRAINAGE SYSTEM




# SANTA CLARA VALLEY

## Water from Compaction

The addition of water to aquifers from the compaction of clay members results from the lowering of water levels (and pressures) in these aquifers. The clay members achieve equilibrium through a reduction in pore pressure which causes a reduction of the volume of the clays. The resultant reduced volume is equal to the amount of water released and is reflected in the amount of overlying land subsidence. The amount of land subsidence for the period 1960-67, as developed by the USGS, is shown on Figure 15. A review of well hydrographs and subsidence data was made, and it is concluded that the subsidence rate could be considered a constant for the 1960-67 period, that subsidence stopped in 1969, and that the rate for 1968 could be considered one half of that for previous years. Annual amounts of water from compaction are listed in the basin inventory, Table 14.

## Ground Water Basin Inventory

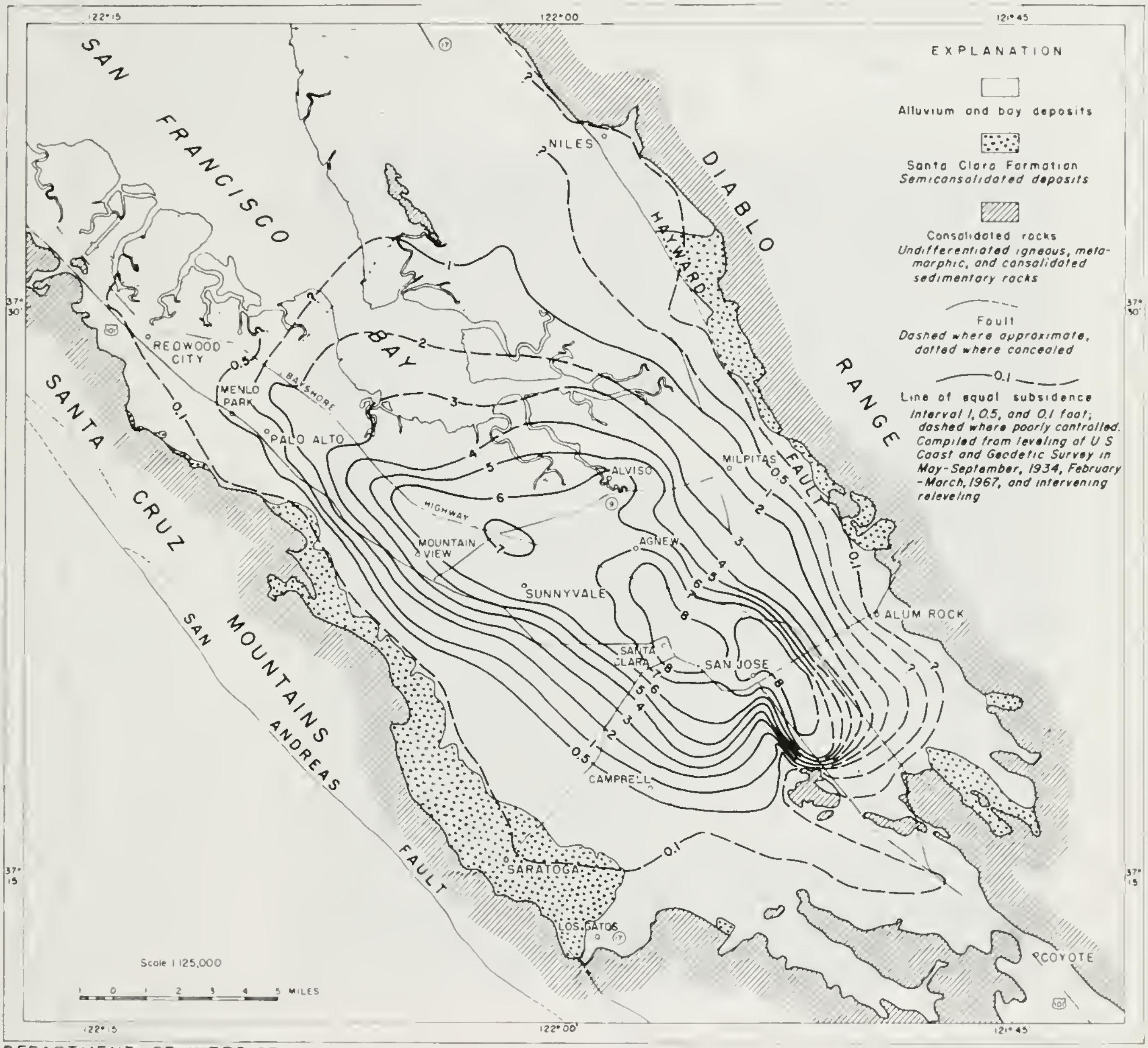
The combination of annual amounts of recharge to and withdrawals from the ground water system is an inventory of the ground water basin and is shown in Table 14. For this study, inflow from and outflow to adjacent areas was assumed to be zero.

## Change in Storage

The annual change in the amounts of water in storage in the ground water basin are computed as the product of specific yield and water level changes. The calculations are made for each node and are aggregated to the basin total shown in Table 14. Change in storage calculations are based on water level data for the March through May period to represent the recovered water levels and to eliminate pumping effects as much as possible.

## Use of the Ground Water Model

The objective of developing a ground water model is to have a means of testing the effect of changes in recharge and pumping patterns on the ground water system. The model is also useful in verifying the accuracy of the ground water inventory. The fair agreement between the basin inventory and change in storage is shown in Table 15 and on Figure 16 by the comparison of accumulated change in storage and net recharge. It should be noted that each is plotted with respect to its computation period, and what appeared to be a poor match in Table 15 becomes a fair match when time differences are taken into account. To be assured that the hydrology used




DEPARTMENT OF INTERIOR
UNITED STATES GEOLOGIC SURVEY

Compiled by J F Poland and R L Ireland, March 1968

LAND SUBSIDENCE IN THE SANTA CLARA VALLEY,

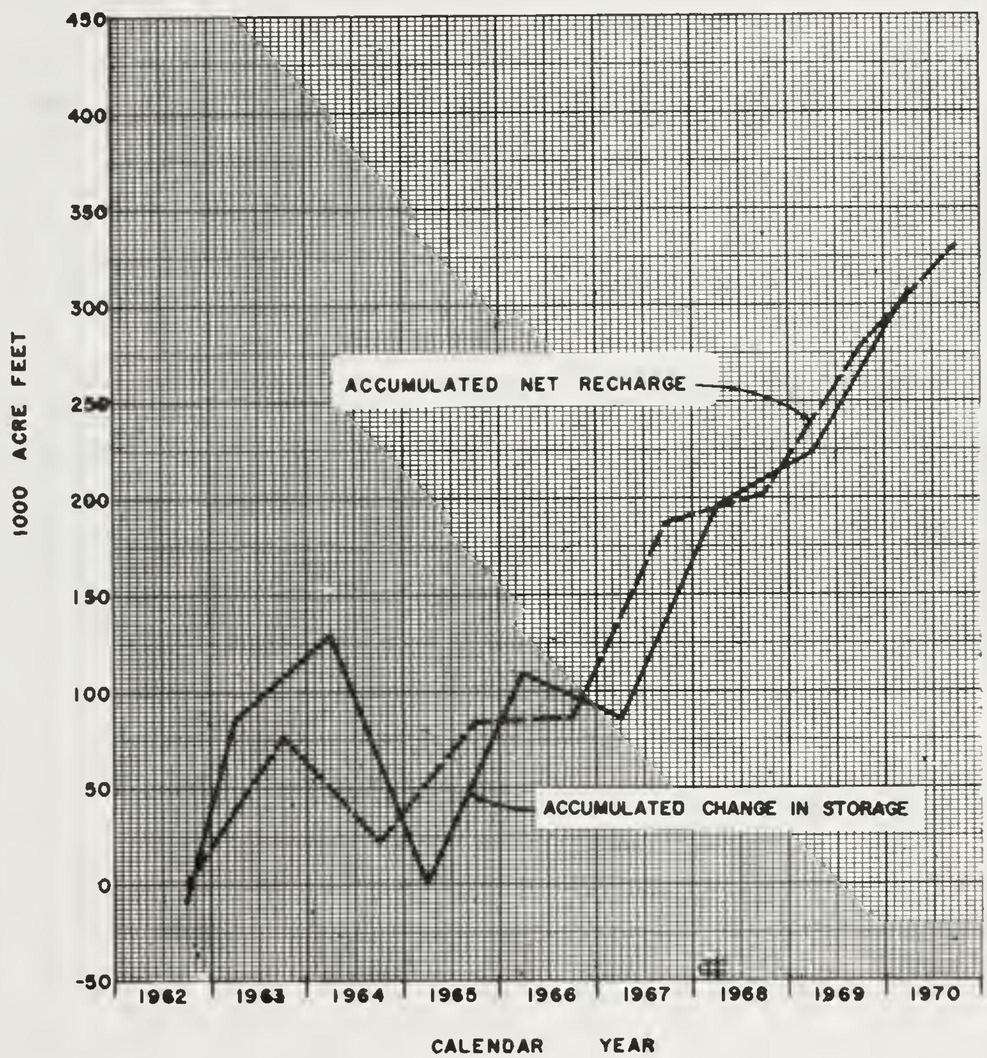
ALAMEDA, SAN MATEO, AND SANTA CLARA COUNTIES, CALIFORNIA

TABLE 15

ACCUMULATED NET RECHARGE AND CHANGE IN STORAGE

| Year | Annual Net Recharge[a/] | Annual Change in Storage[b/] | Accumulated Net Recharge[a/] | Accumulated Change in Storage[a/] |
|---|---|---|---|---|
| | | (thousand acre-feet) | | |
| 61-62 | | -105.5 | | -105.5 |
| 62-63 | 76.1 | 194.5 | 76.1 | 89.0 |
| 63-64 | -53.6 | 40.1 | 22.5 | 129.0 |
| 64-65 | 61.7 | -128.1 | 84.2 | 0.9 |
| 65-66 | 2.3 | 107.6 | 86.5 | 108.5 |
| 66-67 | 100.0 | -21.9 | 186.5 | 86.6 |
| 67-68 | 15.8 | 105.3 | 202.3 | 191.8 |
| 68-69 | 74.7 | 31.6 | 277.0 | 223.4 |
| 69-70 | 52.7 | 84.1 | 329.7 | 307.5 |
| | | (cubic hectometers) | | |
| 61-62 | | *-130.1* | | *-130.1* |
| 62-63 | *93.9* | *239.9* | *93.9* | *109.8* |
| 63-64 | *-66.1* | *49.5* | *27.8* | *159.1* |
| 64-65 | *76.1* | *-158.0* | *103.9* | *1.1* |
| 65-66 | *2.8* | *132.7* | *106.7* | *133.8* |
| 66-67 | *123.4* | *-27.0* | *230.0* | *106.8* |
| 67-68 | *19.4* | *129.9* | *249.5* | *236.6* |
| 68-69 | *92.1* | *39.0* | *341.7* | *275.6* |
| 69-70 | *65.0* | *103.7* | *406.7* | *379.3* |

a/ Computed on water year, October 1.
b/ Computed on April 1.




ACCUMULATED NET RECHARGE
AND CHANGE IN STORAGE

is accurate, it is also necessary to obtain a fair match between historic water levels and model output water levels for most of the nodal areas of the model (Figure 7).

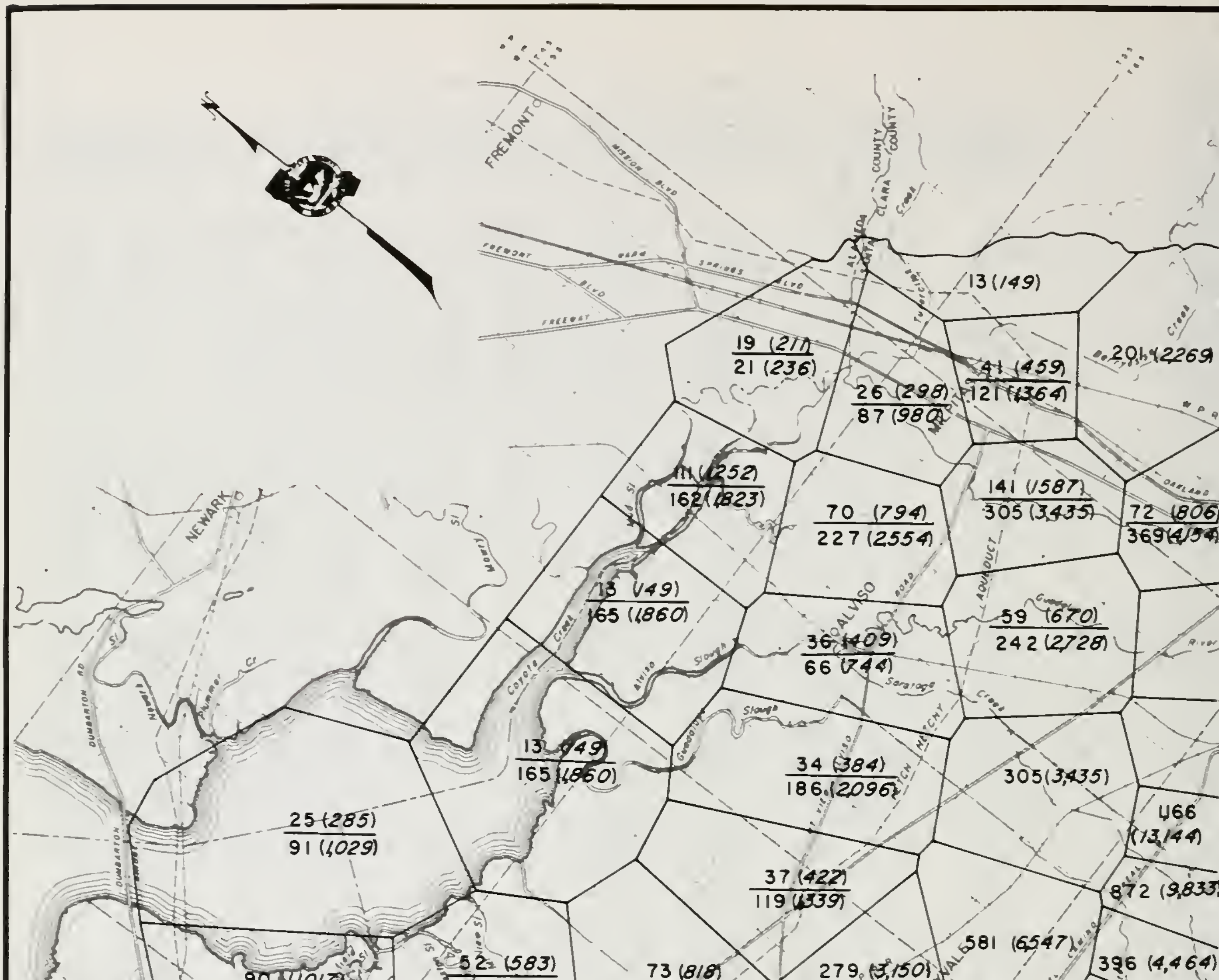
The development of input for each node of the model is identical to computation of net recharge previously described. In addition, during the verification process, some of the transmissivity values between nodes were reduced from the maximum values obtained for the full depth of alluvium to a value that takes into account the effects of faults on ground water movement. The initial transmissivity values used for each node are shown on Figure 17. These values were then modified to obtain the estimated transmissivities along each branch of the nodal system. Branch transmissivities were adjusted for each computer run until the computer output approximated the historic water levels. Table 16 shows the final branch transmissivities; Figure 18 shows the branch numbers used in the model.

The comparison of computed water levels and historic water levels for several nodes is shown on Figure 19. Agreement between these two levels was not possible for many nodes because of a lack of water level data for the study period. Historic water levels probably were affected throughout the study period by potentiometric pressures exerted by the deeper semi-confined and fully-confined aquifers. In addition, changes in pumping patterns during the early part of the study period probably caused significant pressure changes in the deeper aquifers.

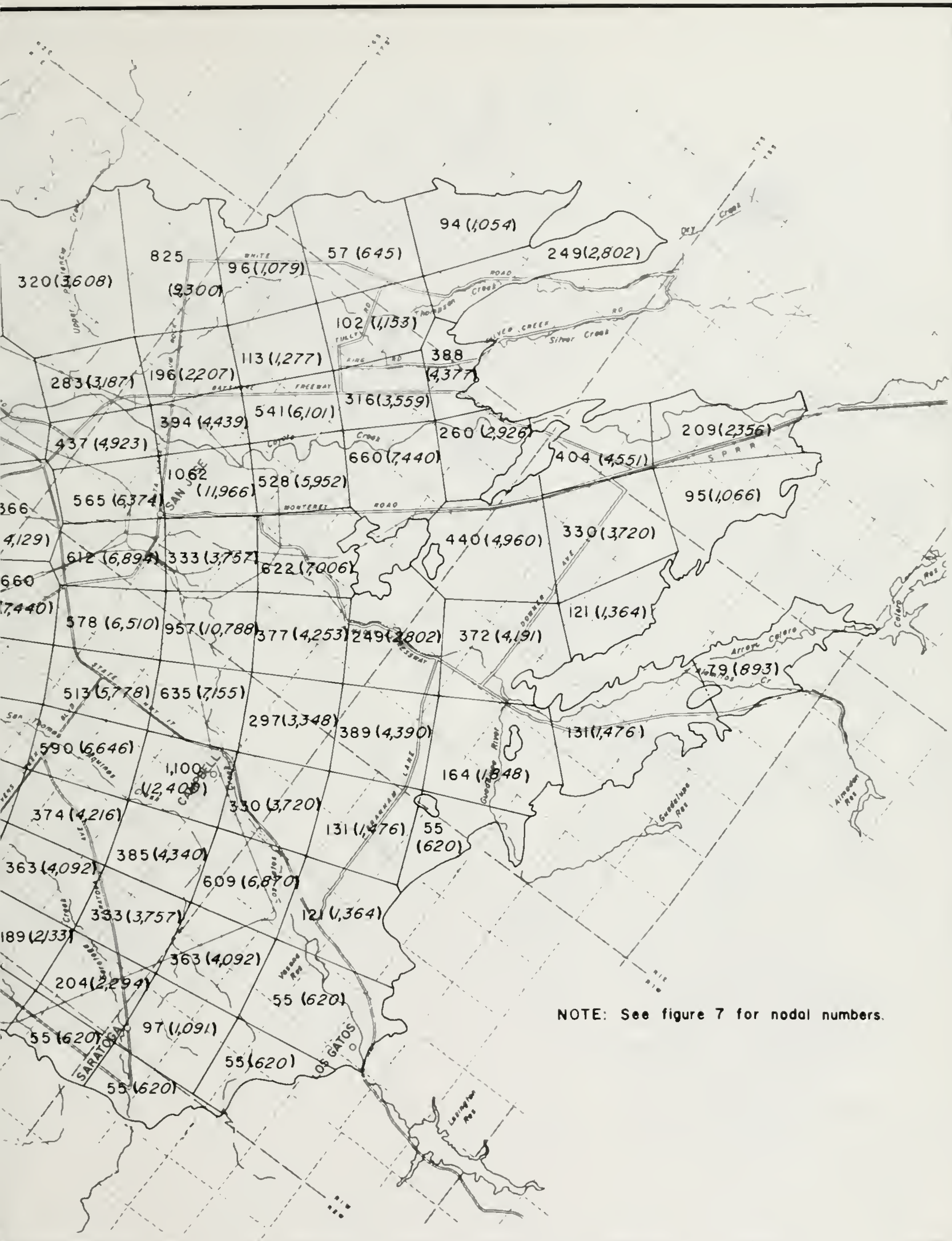
Table 16

FINAL BRANCH TRANSMISSIVITY USED IN GROUND WATER MODEL

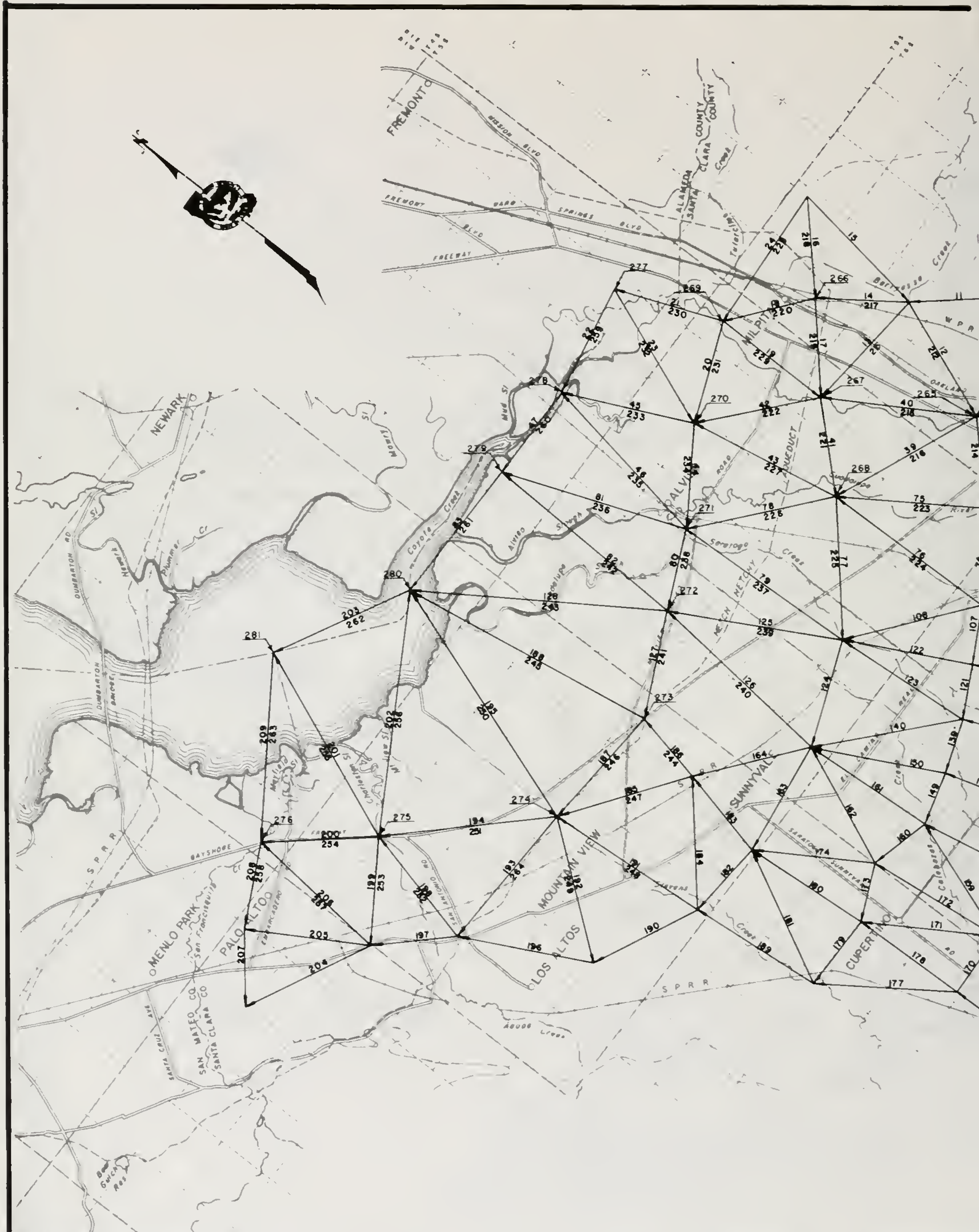
| Branch No. | Transmissivity: Acre-Feet Per Year Per Foot | Transmissivity: Square Meters Per Day | Branch No. | Transmissivity: Acre-Feet Per Year Per Foot | Transmissivity: Square Meters Per Day | Branch No. | Transmissivity: Acre-Feet Per Year Per Foot | Transmissivity: Square Meters Per Day | Branch No. | Transmissivity: Acre-Feet Per Year Per Foot | Transmissivity: Square Meters Per Day |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.00 | 33.26 | 71 | 350.00 | 3880.45 | 141 | 15.00 | 166.30 | 211 | 20.00 | 221.74 |
| 2 | 3.00 | 33.26 | 72 | 515.00 | 5709.80 | 142 | 20.00 | 221.74 | 212 | 10.00 | 110.87 |
| 3 | 3.00 | 33.26 | 73 | 600.00 | 6652.20 | 143 | 20.00 | 221.74 | 213 | 400.00 | 4434.80 |
| 4 | 6.00 | 66.52 | 74 | 485.00 | 5377.19 | 144 | 100.00 | 1108.70 | 214 | 300.00 | 3326.10 |
| 5 | 3.00 | 33.26 | 75 | 77.00 | 853.69 | 145 | 150.00 | 1663.05 | 215 | 350.00 | 3880.45 |
| 6 | 20.00 | 221.74 | 76 | 77.00 | 853.69 | 146 | 345.00 | 3825.01 | 216 | 350.00 | 3880.45 |
| 7 | 5.00 | 55.44 | 77 | 50.00 | 554.35 | 147 | 200.00 | 2217.40 | 217 | 10.00 | 110.87 |
| 8 | 30.00 | 332.61 | 78 | 43.00 | 476.74 | 148 | 350.00 | 3880.45 | 218 | 4.00 | 44.34 |
| 9 | 10.00 | 110.87 | 79 | 37.00 | 410.22 | 149 | 460.00 | 5100.02 | 219 | 20.00 | 221.74 |
| 10 | 14.00 | 155.21 | 80 | 37.00 | 410.21 | 150 | 200.00 | 2217.40 | 220 | 95.00 | 1053.26 |
| 11 | 20.00 | 221.74 | 81 | 13.00 | 144.13 | 151 | 15.00 | 166.30 | 221 | 260.00 | 2882.62 |
| 12 | 10.00 | 110.87 | 82 | 50.00 | 554.35 | 152 | 15.00 | 166.30 | 222 | 255.00 | 2827.18 |
| 13 | 10.00 | 110.87 | 83 | 34.00 | 376.95 | 153 | 15.00 | 166.30 | 223 | 350.00 | 3880.45 |
| 14 | 10.00 | 110.87 | 84 | 280.00 | 3104.36 | 154 | 20.00 | 221.74 | 224 | 500.00 | 5543.50 |
| 15 | 10.00 | 110.87 | 85 | 220.00 | 2439.14 | 155 | 15.00 | 166.30 | 225 | 200.00 | 2217.40 |
| 16 | 2.00 | 22.17 | 86 | 450.00 | 4989.15 | 156 | 150.00 | 1663.05 | 226 | 350.00 | 3880.45 |
| 17 | 6.00 | 66.52 | 87 | 200.00 | 2217.40 | 157 | 15.00 | 166.30 | 227 | 235.00 | 2605.44 |
| 18 | 30.00 | 332.61 | 88 | 450.00 | 4989.15 | 158 | 250.00 | 2771.75 | 228 | 4.00 | 44.34 |
| 19 | 55.00 | 609.78 | 89 | 200.00 | 2217.40 | 159 | 20.00 | 221.74 | 229 | 180.00 | 1995.66 |
| 20 | 40.00 | 443.48 | 90 | 480.00 | 5321.76 | 160 | 550.00 | 6097.85 | 230 | 55.00 | 609.78 |
| 21 | 15.00 | 166.30 | 91 | 500.00 | 5543.50 | 161 | 300.00 | 3326.10 | 231 | 155.00 | 1718.48 |
| 22 | 55.00 | 609.78 | 92 | 595.00 | 6596.76 | 162 | 400.00 | 4434.80 | 232 | 60.00 | 665.22 |
| 23 | 18.00 | 199.56 | 93 | 550.00 | 6097.85 | 163 | 360.00 | 3991.32 | 233 | 260.00 | 2882.62 |
| 24 | 2.00 | 22.17 | 94 | 400.00 | 4434.80 | 164 | 500.00 | 5543.50 | 234 | 45.00 | 498.91 |
| 25 | 10.00 | 110.87 | 95 | 575.00 | 6375.02 | 165 | 20.00 | 221.74 | 235 | 180.00 | 1995.66 |
| 26 | 1.00 | 11.08 | 96 | 210.00 | 2328.27 | 166 | 20.00 | 221.74 | 236 | 160.00 | 1773.93 |
| 27 | 25.00 | 277.17 | 97 | 150.00 | 1663.05 | 167 | 15.00 | 166.30 | 237 | 300.00 | 3326.10 |
| 28 | 13.00 | 144.13 | 98 | 280.00 | 3104.36 | 168 | 15.00 | 166.30 | 238 | 125.00 | 1385.87 |
| 29 | 23.00 | 255.00 | 99 | 340.00 | 3769.58 | 169 | 15.00 | 166.30 | 239 | 170.00 | 1884.79 |
| 30 | 125.00 | 1385.87 | 100 | 350.00 | 3880.45 | 170 | 5.00 | 55.43 | 240 | 250.00 | 2771.75 |
| 31 | 31.00 | 343.69 | 101 | 335.00 | 3714.14 | 171 | 1.00 | 11.08 | 241 | 145.00 | 1607.61 |
| 32 | 155.00 | 1718.48 | 102 | 640.00 | 7095.68 | 172 | 15.00 | 166.30 | 242 | 210.00 | 2328.27 |
| 33 | 26.00 | 228.26 | 103 | 670.00 | 7428.29 | 173 | 20.00 | 221.74 | 243 | 185.00 | 2051.09 |
| 34 | 215.00 | 2383.70 | 104 | 700.00 | 7760.90 | 174 | 470.00 | 5210.89 | 244 | 120.00 | 1330.44 |
| 35 | 36.00 | 399.13 | 105 | 660.00 | 7317.42 | 175 | 15.00 | 166.30 | 245 | 150.00 | 1663.05 |
| 36 | 100.00 | 1108.70 | 106 | 660.00 | 7317.42 | 176 | 15.00 | 166.30 | 246 | 85.00 | 942.39 |
| 37 | 120.00 | 1330.44 | 107 | 800.00 | 8869.60 | 177 | 1.00 | 11.08 | 247 | 90.00 | 997.83 |
| 38 | 87.00 | 964.56 | 108 | 400.00 | 4434.80 | 178 | 5.00 | 55.43 | 248 | 120.00 | 1330.44 |
| 39 | 60.00 | 665.22 | 109 | 110.00 | 1219.57 | 179 | 25.00 | 277.17 | 249 | 205.00 | 2272.83 |
| 40 | 75.00 | 831.52 | 110 | 135.00 | 1496.74 | 180 | 80.00 | 886.96 | 250 | 125.00 | 1385.87 |
| 41 | 70.00 | 776.09 | 111 | 4.00 | 44.34 | 181 | 56.00 | 620.87 | 251 | 65.00 | 720.65 |
| 42 | 72.00 | 798.26 | 112 | 125.00 | 1385.87 | 182 | 72.00 | 798.26 | 252 | 88.00 | 975.65 |
| 43 | 57.00 | 631.95 | 113 | 50.00 | 554.35 | 183 | 124.00 | 1374.78 | 253 | 65.00 | 720.65 |
| 44 | 45.00 | 498.91 | 114 | 300.00 | 3326.10 | 184 | 48.00 | 532.17 | 254 | 500.00 | 5543.50 |
| 45 | 80.00 | 886.96 | 115 | 200.00 | 2217.40 | 185 | 77.00 | 853.69 | 255 | 125.00 | 1385.87 |
| 46 | 65.00 | 720.65 | 116 | 435.00 | 4822.84 | 186 | 50.00 | 554.35 | 256 | 145.00 | 1607.61 |
| 47 | 75.00 | 831.52 | 117 | 825.00 | 9146.77 | 187 | 55.00 | 609.78 | 257 | 550.00 | 6097.85 |
| 48 | 50.00 | 554.35 | 118 | 600.00 | 6652.20 | 188 | 25.00 | 277.17 | 258 | 685.00 | 7594.59 |
| 49 | 20.00 | 221.74 | 119 | 575.00 | 6375.02 | 189 | 75.00 | 831.52 | 259 | 259.00 | 2871.53 |
| 50 | 100.00 | 1108.70 | 120 | 800.00 | 8869.60 | 190 | 35.00 | 388.04 | 260 | 265.00 | 2938.05 |
| 51 | 350.00 | 3880.45 | 121 | 700.00 | 7760.90 | 191 | 90.00 | 997.83 | 261 | 215.00 | 2383.70 |
| 52 | 100.00 | 1108.70 | 122 | 600.00 | 6652.20 | 192 | 70.00 | 776.09 | 262 | 170.00 | 1884.79 |
| 53 | 375.00 | 4157.62 | 123 | 500.00 | 5543.50 | 193 | 75.00 | 831.52 | 263 | 495.00 | 5488.06 |
| 54 | 300.00 | 3326.10 | 124 | 245.00 | 2716.31 | 194 | 65.00 | 720.65 | 264 | 75.00 | 831.52 |
| 55 | 410.00 | 4545.67 | 125 | 45.00 | 498.91 | 195 | 45.00 | 498.91 | 265 | .08 | 0.88 |
| 56 | 285.00 | 3159.79 | 126 | 55.00 | 609.78 | 196 | 110.00 | 1219.57 | 266 | .04 | 0.44 |
| 57 | 145.00 | 1607.61 | 127 | 40.00 | 443.48 | 197 | 200.00 | 2217.40 | 267 | .05 | 0.55 |
| 58 | 200.00 | 2217.40 | 128 | 30.00 | 332.61 | 198 | 57.00 | 631.95 | 268 | .05 | 0.55 |
| 59 | 400.00 | 4434.80 | 129 | 5.00 | 55.43 | 199 | 30.00 | 332.61 | 269 | .03 | 0.33 |
| 60 | 450.00 | 4989.15 | 130 | 4.00 | 44.34 | 200 | 62.00 | 687.39 | 270 | .04 | 0.44 |
| 61 | 200.00 | 2217.40 | 131 | 20.00 | 221.74 | 201 | 40.00 | 443.48 | 271 | .04 | 0.44 |
| 62 | 105.00 | 1164.13 | 132 | 50.00 | 554.35 | 202 | 300.00 | 3326.10 | 272 | .04 | 0.44 |
| 63 | 415.00 | 4601.10 | 133 | 125.00 | 1385.87 | 203 | 25.00 | 277.17 | 273 | .04 | 0.44 |
| 64 | 200.00 | 2217.40 | 134 | 200.00 | 2217.40 | 204 | 90.00 | 997.83 | 274 | .01 | 0.11 |
| 65 | 290.00 | 3215.23 | 135 | 700.00 | 7760.90 | 205 | 495.00 | 5488.06 | 275 | .02 | 0.22 |
| 66 | 600.00 | 6652.20 | 136 | 770.00 | 8536.99 | 206 | 80.00 | 886.96 | 276 | .04 | 0.44 |
| 67 | 300.00 | 3326.10 | 137 | 440.00 | 4878.28 | 207 | 590.00 | 6541.33 | 277 | .03 | 0.33 |
| 68 | 720.00 | 7982.64 | 138 | 670.00 | 7428.29 | 208 | 80.00 | 886.96 | 278 | .04 | 0.44 |
| 69 | 350.00 | 3880.45 | 139 | 580.00 | 6430.46 | 209 | 57.00 | 631.95 | 279 | .03 | 0.33 |
| 70 | 810.00 | 8980.47 | 140 | 200.00 | 2217.40 | 210 | 225.00 | 2494.57 | 280 | .02 | 0.22 |
| | | | | | | | | | 281 | .02 | 0.22 |



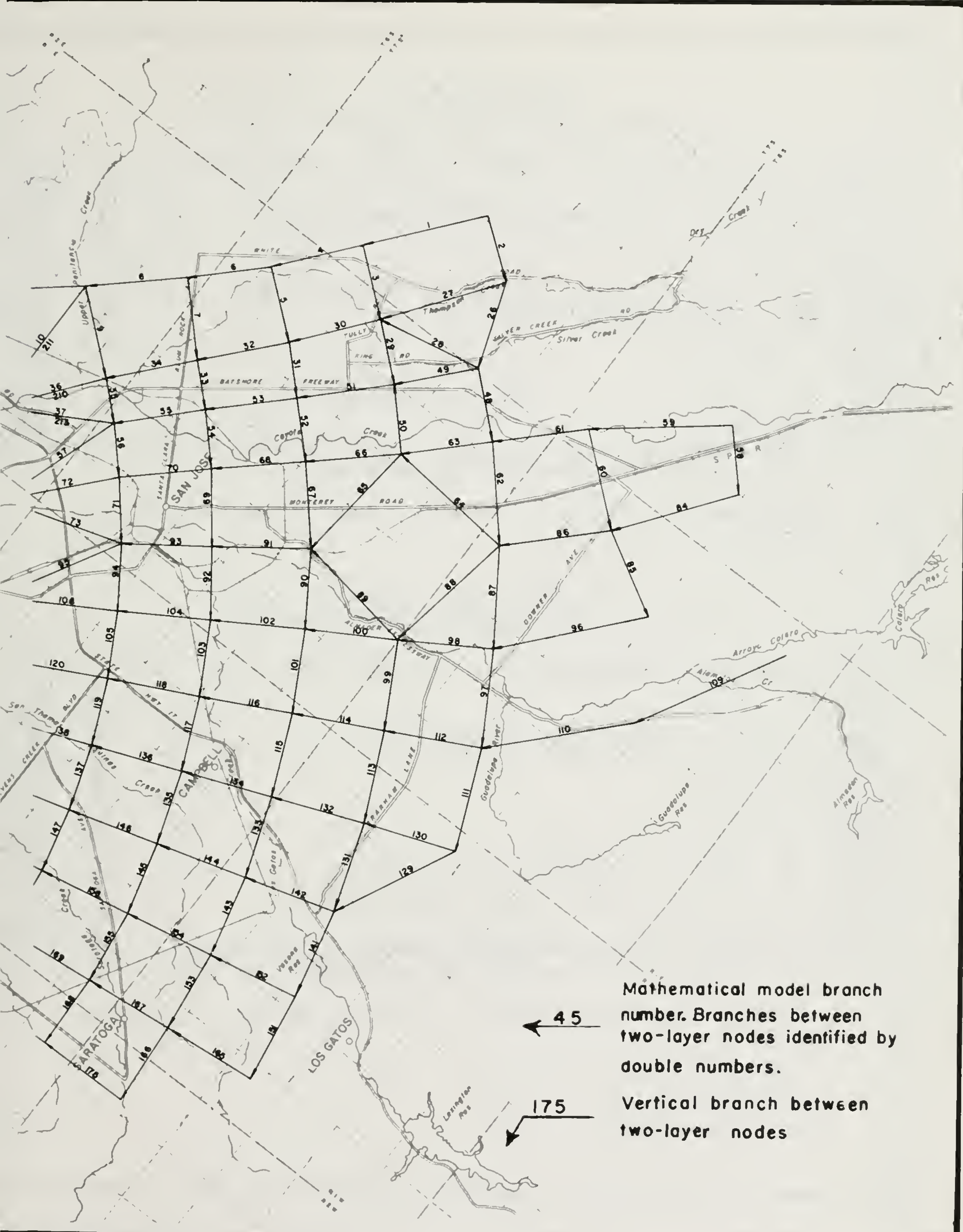

# INITIAL TRANS-




MISSIVITY VALUES



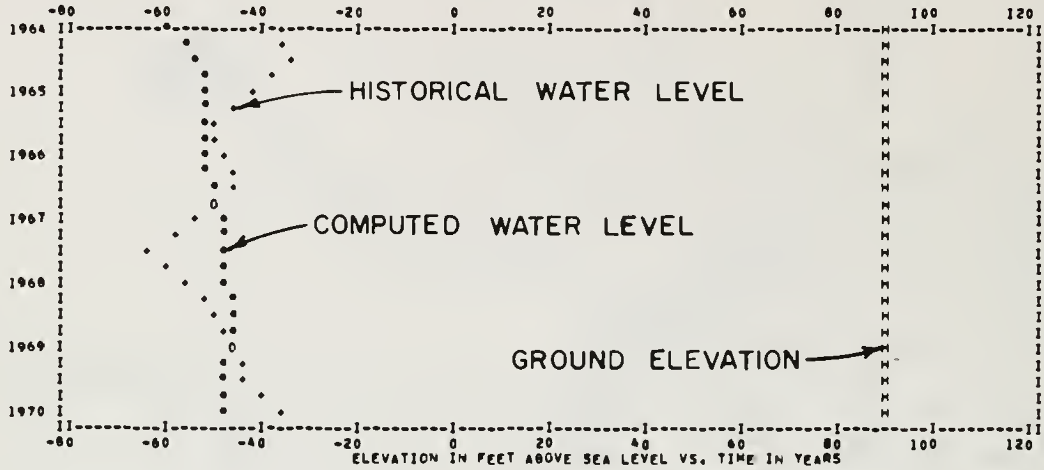

# MATHEMATICAL MODEL




# BRANCH NUMBERS

## NODE 20

NORTH SANTA CLARA GROUND WATER MODEL WITH ORIGINAL WATER LEVELS

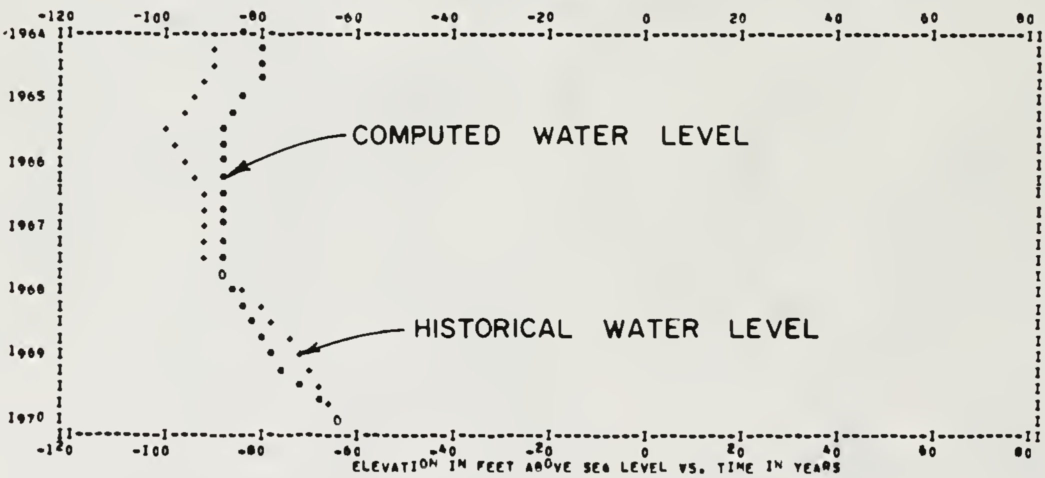



| COMPT. | HIST. |
|---|---|
| -60 | -37 |
| -57 | -36 |
| -55 | -35 |
| -53 | -39 |
| -53 | -43 |
| -53 | -47 |
| -53 | -51 |
| -53 | -50 |
| -52 | -49 |
| -52 | -47 |
| -51 | -46 |
| -50 | -50 |
| -49 | -55 |
| -49 | -59 |
| -48 | -64 |
| -48 | -60 |
| -48 | -57 |
| -47 | -53 |
| -46 | -50 |
| -47 | -49 |
| -47 | -47 |
| -48 | -45 |
| -49 | -44 |
| -49 | -40 |
| -49 | -36 |
| (*) | (+) |

BOTTOM AQUIFER ELEVATION= -500 TOP AQUIFER ELEVATION= 90 (COMPT)-(HIST)= -13

## NODE 70

NORTH SANTA CLARA GROUND WATER MODEL WITH ORIGINAL WATER LEVELS




| COMPT. | HIST. |
|---|---|
| -85 | -93 |
| -81 | -91 |
| -80 | -90 |
| -81 | -92 |
| -84 | -95 |
| -87 | -97 |
| -88 | -100 |
| -89 | -98 |
| -88 | -96 |
| -88 | -94 |
| -88 | -92 |
| -88 | -92 |
| -89 | -92 |
| -89 | -93 |
| -89 | -93 |
| -88 | -89 |
| -86 | -85 |
| -84 | -81 |
| -82 | -78 |
| -81 | -75 |
| -79 | -73 |
| -76 | -70 |
| -73 | -68 |
| -69 | -66 |
| -65 | -65 |
| (*) | (+) |

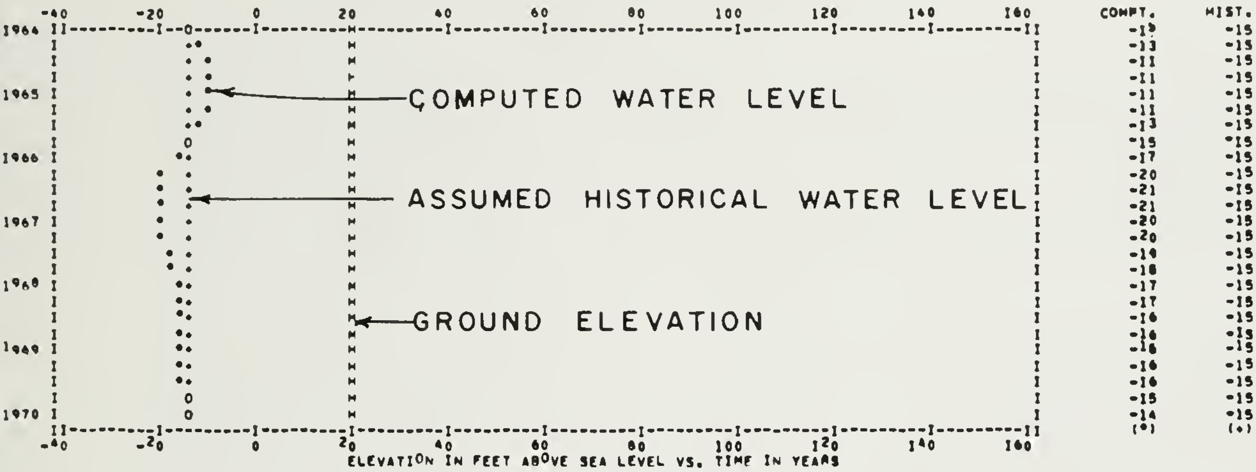
BOTTOM AQUIFER ELEVATION= -670 TOP AQUIFER ELEVATION= 150 (COMPT)-(HIST)= 0

For nodal locations, see figure 7

FINAL COMPUTER

## NODE 10 (UPPER NODE)

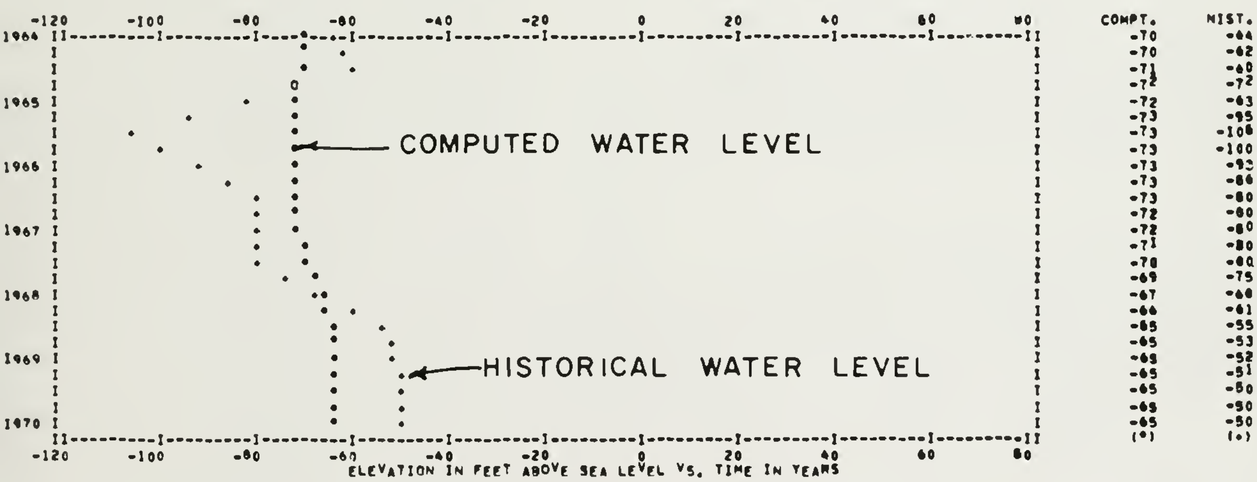
NORTH SANTA CLARA GROUND WATER MODEL WITH ORIGINAL WATER LEVELS




BOTTOM AQUIFER ELEVATION= -100 TOP AQUIFER ELEVATION= 20 (COMPT)-(HIST)= 1

## NODE 102 (LOWER NODE)

NORTH SANTA CLARA GROUND WATER MODEL WITH ORIGINAL WATER LEVELS




BOTTOM AQUIFER ELEVATION= -650 TOP AQUIFER ELEVATION= -140 (COMPT)-(HIST)= -15

NOTE: Nodes 10 and 102 comprise a two layer node.

OUTPUT

# CHAPTER V. GROUND WATER BASIN SURVEILLANCE SYSTEM

During the 1950's, surveillance of ground water in Santa Clara County consisted of measuring the static and pumping depths to the water surface and analysis of the water being pumped. Because the intent of the program was only to monitor the water coming from the well, little attention was given to the individual aquifer, or group of aquifers, producing the water. Since that time, however, increasing interest and concern has been placed on all of the ground water resources of California. As a result, there was and is a need to know considerably more about the ground water resource -- how water infiltrates to the ground water body, how and by what paths it moves from point to point through the ground water body, how it can become polluted or degraded, and the effects of its removal from the ground water body. This last item was of particular importance in Santa Clara County because overpumping of the ground water basin had caused land subsidence, and there was an urgent need to develop plans to prevent further subsidence.

Data required to adequately monitor the Santa Clara Valley ground water basin include the following eight items:

1. Pumpage. Metered ground water pumpage by water year (October through September) is necessary to enable the accurate determination of an annual water balance; metered pumpage by season will be necessary in formulating operational plans because the ground water resource is intensely used and responds rapidly to changes in pumping rates.

2. Unconfined Water Levels. Periodic ground water elevation data for selected locations in the unconfined ground water zone will be necessary to accurately determine change in storage. Most elevation determinations can be seasonal, but a few continuous recorders are necessary in order to determine if the seasonal measurements were taken during periods of maximum recovery and lowering of water levels.

3. Confined Water Levels. Elevation data of the confined potentiometric surface should be developed on a seasonal basis. These data are needed to help define the degree of ground water movement between the various confined aquifer systems by providing data on pressure differences between aquifers.

4. Surface Inflow. A sufficient number of gaging stations along the perimeter of the ground water basin are required to form reliable estimates of flow, by correlation, of all ungaged streams. A reliable streamflow station at Coyote Narrows will provide much-needed data on surface inflow to the basin.

5. Local Runoff. A series of areas representing differing natural and developed areas should be instrumented with precipitation and flow instruments to determine contribution of valley areas to streamflow. Such areas could also be used to develop and test methods of increasing recharge on urban lands by use of landscaping techniques. These techniques would include use of native plants to reduce water use and grading to retain storm waters on pervious areas.

6. Artificial Recharge. Accurate inflow and outflow measurements for all percolation facilities, including both ponds and streams, are necessary to provide reliable data on the quantity of water recharged artificially to the basin.

7. Surface Outflow. A sufficient number of gages on streams draining into the Bay are required to provide reliable estimates of quantities of surface water leaving the basin. Along with data from 4, 5, and 6, reasonable estimates of total recharge can be made.

8. Transmissivity. A program of field testing of selected water wells would provide accurate data on aquifer transmissivities.

9. Water Quality. Monitoring of both surface and ground water quality is necessary to determine the health of the basin and to detect possible threats before they proceed beyond control. Quality data for each surface water measuring station, taken for a wide range of flows, will provide information on fluctuations of mineral constitutents entering and leaving the basin. Similar data from each monitoring well will provide data on the mineral characteristics of the various parts of the aquifer system. The frequency of sampling and the analyses for specific mineral constituents will vary widely depending on location and development pattern.

During the conduct of the study, it was apparent that of all the above data requirements, the two needing immediate attention are the unconfined water levels (No. 2) and water quality (No. 9).

The balance of this chapter discusses design of a basic ground water measurement network and implementation of such a network for the unconfined zone. Design for water quality purposes is more complicated than design of a quantity measurement network since it must incorporate the influences of soils, vegetation, geology, geomorphology, hydrology, and land use. The design of a water quality surveillance network is not discussed in this report but is the objective of a separate cooperative study.

## Water Level Measurements

A data gathering system which will provide information on the elevation of the upper surface of the free (unconfined) ground water body must be based on the following: (1) adequate knowledge of the subsurface geology, (2) adequate knowledge of the subsurface hydrology, and (3) adequate knowledge of construction details of each monitoring well. The first two requirements have been met by the study reported on in this bulletin. An appraisal of the existing ground water level network was made in order to evaluate the third requirement. All of the wells used for measuring ground water levels during the period 1962 through 1972 were reviewed. So that a meaningful relationship between water levels and aquifers can be developed, it is necessary that both a driller's log and construction details be available for each well that is measured. Of the 482 wells from which water level data were available for the study period, only 183 had construction details available. Of the remaining, water level data were available from 95 wells for which total depth was unknown.

A further requirement in the determination of the configuration of the unconfined ground water surface is that the monitoring wells should tap only those aquifers which do not have any significant degree of confinement. In North Santa Clara Valley, wells that are generally deeper than about 300 feet will be drawing water from aquifers that are under some degree of confinement. A review of the monitoring well data indicated that there were very few wells being measured that have logs and are less than 300 feet deep. This lack of qualified measuring wells and meaningful water level data was the prime reason that the mathematical model could not be fully verified. Table 17 lists wells that were measured during the study period and those measured through 1974. Shown in the table is information on the availability of construction data. Because of the general lack of adequate construction data for the wells measured, it is not possible to incorporate the majority of them into a meaningful water-level measurement network. Hence, a new water level measurement network should be implemented.

## Well Qualification

The first step in selecting wells for a new measurement network is determining what aquifer, or group of aquifers, the measurements of the well would represent. This step is called well qualification. A qualified well is defined as being one that meets all of the following criteria:

1. Well is accurately located. This is essential, because where several wells are grouped in a cluster, measurements may not always be for the same well.

2. Well log is available and on file with agency performing monitoring operations. Electric log of well, although not entirely necessary, is desirable.

3. Well construction data are available to agency performing monitoring operations.

TABLE 17

NORTH SANTA CLARA WELL QUALIFICATION LISTING

| WELL LOCATION NUMBER | PERIOD OF RECORD | DEPTH IN FEET | PERFORATED INTERVAL IN FEET | REMARKS |
|---|---|---|---|---|
| 5S 1E31E01 | 62-71 | 200 | | DESTROYED |
| 5S 1E31R01 | 62-71 | 160 | | NO CONSTRUCTION DATA |
| 5S 1W36E01 | 71- | 392 | | CONFIDENTIAL LOG |
| 5S 2W32F10 | 71- | 218 | 185-198 | |
| 5S 2W34N01 | 71- | 94 | 77-82 | |
| 5S 2W34N02 | 71- | 262 | 177-184 | |
| 5S 2W35R01 | 71- | 280 | 190,280 | |
| 5S 2W35R02 | 71- | 80 | 60 | |
| 6S 1E04Q01 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1E05P01 | 70-72 | 752 | | NO CONSTRUCTION DATA |
| 6S 1E05Q02 | 53- | 200 | | NO CONSTRUCTION DATA |
| 6S 1E06N01 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1E06P02 | 59- | 125 | | NO CONSTRUCTION DATA |
| 6S 1E15Q01 | 53-71 | 414 | | DESTROYED |
| 6S 1E16K03 | 69- | 830 | | CONFIDENTIAL LOG |
| 6S 1E17B01 | 39-71 | 565 | | DESTROYED |
| 6S 1E17G06 | 69- | 652 | | CONFIDENTIAL LOG |
| 6S 1E17M01 | 59- | 300 | | NO CONSTRUCTION DATA |
| 6S 1E17P03 | 70- | 450 | | NO CONSTRUCTION DATA |
| 6S 1E17Q01 | 70- | 81 | | NO CONSTRUCTION DATA |
| 6S 1E17R01 | 59- | 450 | | NO CONSTRUCTION DATA |
| 6S 1E17R02 | 54-71 | | | DESTROYED |
| 6S 1E18K01 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1E20H01 | 69-71 | | | DESTROYED |
| 6S 1E20J01 | 36- | 500 | | NO CONSTRUCTION DATA |
| 6S 1E20Q02 | 70- | 100 | | NO CONSTRUCTION DATA |
| 6S 1E21R01 | 51- | 580 | 186-552 | |
| 6S 1E23P01 | 36- | 295 | | NO CONSTRUCTION DATA |
| 6S 1E27B01 | 52- | 476 | | NO CONSTRUCTION DATA |
| 6S 1E27E01 | 69- | 400 | | NO CONSTRUCTION DATA |
| 6S 1E27M02 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1E27N02 | 57- | 300 | | NO CONSTRUCTION DATA |
| 6S 1E27P02 | 36- | 400 | | NO CONSTRUCTION DATA |
| 6S 1E27Q02 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1E28H03 | 52- | 444 | 215-434 | |
| 6S 1E29G06 | 59- | 560 | 288-535 | |
| 6S 1E29J05 | 36-71 | 475 | 181-469 | |
| 6S 1E30D10 | 69- | 800 | | NO CONSTRUCTION DATA |
| 6S 1E30D02 | 70- | 130 | | NO CONSTRUCTION DATA |
| 6S 1E30M01 | 36- | 206 | | NO CONSTRUCTION DATA |
| 6S 1E30N01 | 69- | 625 | 427-615 | TOO DEEP FOR NETWORK |
| 6S 1E30R01 | 51- | 238 | | NO CONSTRUCTION DATA |
| 6S 1E31A02 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1E31K02 | 57- | 667 | 382-642 | |
| 6S 1E31M02 | 70- | 86 | | NO CONSTRUCTION DATA |
| 6S 1E32G01 | 69- | 800 | 315-745 | |
| 6S 1E32M05 | 70- | 110 | | NO CONSTRUCTION DATA |
| 6S 1E32R01 | 69- | 310 | | NO CONSTRUCTION DATA |
| 6S 1E33F06 | 69- | 612 | 267-603 | |

TABLE 17 (CONTINUED)

NORTH SANTA CLARA WELL QUALIFICATION LISTING

| WELL LOCATION NUMBER | PERIOD OF RECORD | DEPTH IN FEET | PERFORATED INTERVAL IN FEET | REMARKS |
|---|---|---|---|---|
| 6S 1E34B01 | 71- | 380 | 221-367 | |
| 6S 1E34B02 | 36- | 400 | 125-379 | |
| 6S 1E34D01 | 71- | | | NO CONSTRUCTION DATA |
| 6S 1E34D02 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1E34K01 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1E34M01 | 67- | 300 | | NO CONSTRUCTION DATA |
| 6S 1E35M10 | 69- | 550 | | CONFIDENTIAL LOG |
| 6S 1W01F03 | 68- | | | NO CONSTRUCTION DATA |
| 6S 1W05L01 | 71- | 84 | 74-84 | |
| 6S 1W05L02 | 71- | 252 | 220-252 | |
| 6S 1W05L03 | 71- | 336 | 310-336 | |
| 6S 1W09G02 | 70- | 370 | | CONFIDENTIAL LOG |
| 6S 1W10K01 | 70- | 500 | | NO CONSTRUCTION DATA |
| 6S 1W10M01 | 70- | 560 | 228-545 | |
| 6S 1W11G02 | 52-64 | 570 | | DESTROYED |
| 6S 1W11P01 | 57- | 525 | | NO CONSTRUCTION DATA |
| 6S 1W12M02 | 59- | 320 | | NO CONSTRUCTION DATA |
| 6S 1W12M05 | 69- | 640 | | NO CONSTRUCTION DATA |
| 6S 1W12R01 | 39- | 280 | | NO CONSTRUCTION DATA |
| 6S 1W13E01 | 70- | 619 | 240-586 | TOO DEEP FOR NETWORK |
| 6S 1W14L04 | 70- | 90 | | NO CONSTRUCTION DATA |
| 6S 1W14Q02 | 57- | 516 | 214-516 | |
| 6S 1W15B01 | 69- | | | NO CONSTRUCTION DATA |
| 6S 1W15H01 | 36- | 392 | 228-378 | |
| 6S 1W15N01 | 55- | 469 | 200-460 | |
| 6S 1W15Q01 | 69- | 60 | | NO CONSTRUCTION DATA |
| 6S 1W17M01 | 60- | 600 | 319-580 | TOO DEEP FOR NETWORK |
| 6S 1W19C02 | 59- | 420 | 165-413 | |
| 6S 1W21J01 | 42- | 612 | 208-602 | TOO DEEP FOR NETWORK |
| 6S 1W21R02 | 62- | 492 | 252-458 | |
| 6S 1W21R04 | 36- | 175 | | NO CONSTRUCTION DATA |
| 6S 1W22B01 | 69- | 650 | | CONFIDENTIAL LOG |
| 6S 1W22C01 | 62-71 | | | DESTROYED |
| 6S 1W22H01 | 69- | 750 | | NO CONSTRUCTION DATA |
| 6S 1W23F02 | 69- | 90 | | CONFIDENTIAL LOG |
| 6S 1W23K01 | 60- | 340 | 210-337 | |
| 6S 1W23Q01 | 69- | | | NO CONSTRUCTION DATA |
| 6S 1W24H04 | 69- | 131 | | NO CONSTRUCTION DATA |
| 6S 1W24H08 | 39- | 588 | | NO CONSTRUCTION DATA |
| 6S 1W24K02 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1W25C02 | 45-70 | 282 | | DESTROYED |
| 6S 1W26D02 | 69- | 700 | | CONFIDENTIAL LOG |
| 6S 1W26F03 | 71- | | | NO CONSTRUCTION DATA |
| 6S 1W26H02 | 70- | 100 | | NO CONSTRUCTION DATA |
| 6S 1W26P02 | 70- | 460 | 190-430 | |
| 6S 1W27E02 | 70- | 501 | 184-497 | TOO DEEP FOR NETWORK |
| 6S 1W27K01 | 69- | | | NO CONSTRUCTION DATA |
| 6S 1W27K04 | 69- | 100 | | NO CONSTRUCTION DATA |
| 6S 1W27N04 | 63- | 432 | 170-394 | |

TABLE 17 (CONTINUED)

NORTH SANTA CLARA WELL QUALIFICATION LISTING

| WELL LOCATION NUMBER | PERIOD OF RECORD | DEPTH IN FEET | PERFORATED INTERVAL IN FEET | REMARKS |
|---|---|---|---|---|
| 6S 1W27P01 | 69- | 376 | 234-363 | |
| 6S 1W27P02 | 36- | 607 | | NO CONSTRUCTION DATA |
| 6S 1W28F01 | 70- | 375 | 312-362 | |
| 6S 1W28R02 | 69- | 700 | | NO CONSTRUCTION DATA |
| 6S 1W29Q02 | 51- | 500 | | NO CONSTRUCTION DATA |
| 6S 1W31E01 | 70- | 450 | | NO CONSTRUCTION DATA |
| 6S 1W32C10 | 70- | | | NO CONSTRUCTION DATA |
| 6S 1W32F10 | 69- | | | NO CONSTRUCTION DATA |
| 6S 1W32H01 | 69- | 650 | | NO CONSTRUCTION DATA |
| 6S 1W32L04 | 70- | 90 | | NO CONSTRUCTION DATA |
| 6S 1W32M02 | 70-71 | | | DESTROYED |
| 6S 1W33N01 | 69- | 528 | | NO CONSTRUCTION DATA |
| 6S 1W34A03 | 70- | 672 | | CONFIDENTIAL LOG |
| 6S 1W35K01 | 60- | 445 | | CONFIDENTIAL LOG |
| 6S 1W35L01 | 69- | 458 | | CONFIDENTIAL LOG |
| 6S 1W36A01 | 57- | 300 | | NO CONSTRUCTION DATA |
| 6S 2W03N01 | 70- | 185 | | NO CONSTRUCTION DATA |
| 6S 2W08H01 | 68- | 284 | | NO CONSTRUCTION DATA |
| 6S 2W09Q01 | 49- | 683 | 180-632 | TOO DEEP FOR NETWORK |
| 6S 2W10G02 | 68- | 455 | | NO CONSTRUCTION DATA |
| 6S 2W13F01 | 68- | 615 | | NO CONSTRUCTION DATA |
| 6S 2W13R01 | 69- | 700 | 182-680 | TOO DEEP FOR NETWORK |
| 6S 2W15L18 | 69- | | | NO CONSTRUCTION DATA |
| 6S 2W17P01 | 58- | | | NO CONSTRUCTION DATA |
| 6S 2W17R01 | 69- | 572 | 270-572 | |
| 6S 2W18J01 | 70- | 54 | 30-53 | |
| 6S 2W19B02 | 70- | 465 | 110-292 | |
| 6S 2W19G01 | 56- | 240 | | NO CONSTRUCTION DATA |
| 6S 2W19H03 | 70- | 377 | | CONFIDENTIAL LOG |
| 6S 2W20F04 | 70- | | | NO CONSTRUCTION DATA |
| 6S 2W20L01 | 70- | 472 | 224-448 | |
| 6S 2W20N01 | 69- | 470 | | NO CONSTRUCTION DATA |
| 6S 2W21D08 | 69- | 572 | | CONFIDENTIAL LOG |
| 6S 2W22G01 | 70- | 817 | | CONFIDENTIAL LOG |
| 6S 2W22H04 | 69- | | | NO CONSTRUCTION DATA |
| 6S 2W22M01 | 69- | 206 | | NO CONSTRUCTION DATA |
| 6S 2W22M02 | 69- | 439 | 237-405 | |
| 6S 2W23Q02 | 59- | 428 | | NO CONSTRUCTION DATA |
| 6S 2W25C02 | 36- | 500 | | NO CONSTRUCTION DATA |
| 6S 2W27B01 | 58-71 | | | DESTROYED |
| 6S 2W28D01 | 69- | 410 | | NO CONSTRUCTION DATA |
| 6S 2W28F01 | 70- | | | NO CONSTRUCTION DATA |
| 6S 2W28N01 | 69- | 400 | | NO CONSTRUCTION DATA |
| 6S 2W28N02 | 69- | 600 | 254-577 | |
| 6S 2W29F02 | 61- | 695 | 230-570 | |
| 6S 2W29J02 | 69- | 596 | | NO CONSTRUCTION DATA |
| 6S 2W29K05 | 69- | 600 | | NO CONSTRUCTION DATA |
| 6S 2W29M05 | 69- | 700 | | CONFIDENTIAL LOG |
| 6S 2W32D01 | 69- | 515 | | NO CONSTRUCTION DATA |

NORTH SANTA CLARA WELL QUALIFICATION LISTING

| WELL LOCATION NUMBER | PERIOD OF RECORD | DEPTH IN FEET | PERFORATED INTERVAL IN FEET | REMARKS |
|---|---|---|---|---|
| 6S 2W32D02 | 69- | 950 | | NO CONSTRUCTION DATA |
| 6S 2W33A02 | 69- | 500 | 257-489 | |
| 6S 2W33B01 | 69-72 | 400 | | NO CONSTRUCTION DATA |
| 6S 2W33B99 | 36-71 | 347 | | DESTROYED |
| 6S 2W33C01 | 69- | 1120 | 290-1120 | |
| 6S 2W33H01 | 69- | 520 | | CONFIDENTIAL LOG |
| 6S 2W34B02 | 40- | | | NO CONSTRUCTION DATA |
| 6S 2W34B03 | 67- | 408 | | CONFIDENTIAL LOG |
| 6S 2W34G02 | 69- | 402 | | NO CONSTRUCTION DATA |
| 6S 2W34K02 | 69- | 746 | | CONFIDENTIAL LOG |
| 6S 2W34N01 | 69- | 423 | | NO CONSTRUCTION DATA |
| 6S 2W34N03 | 69- | 620 | | CONFIDENTIAL LOG |
| 6S 2W36J01 | 71-71 | | | NO CONSTRUCTION DATA |
| 7S 1E01G01 | 36 | 400 | | NO CONSTRUCTION DATA |
| 7S 1E01N01 | 71 | 695 | | CONFIDENTIAL LOG |
| 7S 1E02J01 | 69-71 | 420 | | NO CONSTRUCTION DATA |
| 7S 1E02J02 | 71- | | | NO CONSTRUCTION DATA |
| 7S 1E02J06 | 71 | 608 | 280-310 | |
| 7S 1E02L02 | 69 | 443 | | NO CONSTRUCTION DATA |
| 7S 1E03A01 | 69 | 620 | 440-531 | |
| 7S 1E03A02 | 69- | 598 | 290-591 | |
| 7S 1E03H01 | 57 | 356 | 258-351 | |
| 7S 1E03L01 | 36- | 150 | 106-148 | |
| 7S 1E04F02 | 71 | 500 | | NO CONSTRUCTION DATA |
| 7S 1E06L01 | 69 | 398 | | NO CONSTRUCTION DATA |
| 7S 1E06M01 | 36 | 803 | 430-753 | |
| 7S 1E06N02 | 70 | 100 | | NO CONSTRUCTION DATA |
| 7S 1E07F01 | 68 | 501 | | NO CONSTRUCTION DATA |
| 7S 1E07N01 | 53- | 800 | 430-753 | TOO DEEP FOR NETWORK |
| 7S 1E07R05 | 70- | 831 | 528-707 | |
| 7S 1E07R99 | 69 | | | NO CONSTRUCTION DATA |
| 7S 1E08Q10 | 69- | 512 | | NO CONSTRUCTION DATA |
| 7S 1E09D03 | 69 | 560 | 295-467 | |
| 7S 1E09D06 | 36 | 742 | 526-708 | |
| 7S 1E09D99 | 69 | 543 | | NO CONSTRUCTION DATA |
| 7S 1E10P01 | 68 | 300 | | CONFIDENTIAL LOG |
| 7S 1E13D01 | 71 | 160 | | NO CONSTRUCTION DATA |
| 7S 1E13E03 | 52-71 | 410 | | DESTROYED |
| 7S 1E13E06 | 68 | 510 | 156-425 | |
| 7S 1E14P01 | 50 | 240 | | NO CONSTRUCTION DATA |
| 7S 1E15E02 | 36 | 253 | | NO CONSTRUCTION DATA |
| 7S 1E15L04 | 71 | 301 | | NO CONSTRUCTION DATA |
| 7S 1E15N03 | 69 | 800 | 300-780 | |
| 7S 1E16C05 | 69 | 725 | 526-682 | |
| 7S 1E16C06 | 69 | 716 | 508-697 | |
| 7S 1E16C99 | 36- | | | NO CONSTRUCTION DATA |
| 7S 1E16L01 | 69 | 580 | | CONFIDENTIAL LOG |
| 7S 1E17F01 | 71 | 715 | 378-698 | |
| 7S 1E17H06 | 71 | 470 | | CONFIDENTIAL LOG |

TABLE 17 (CONTINUED)

NORTH SANTA CLARA WELL QUALIFICATION LISTING

| WELL LOCATION NUMBER | PERIOD OF RECORD | DEPTH IN FEET | PERFORATED INTERVAL IN FEET | REMARKS |
|---|---|---|---|---|
| 7S 1E18A03 | 69 | 795 | | CONFIDENTIAL LOG |
| 7S 1E18C02 | 69 | 190 | | NO CONSTRUCTION DATA |
| 7S 1E18K03 | 71 | 760 | | CONFIDENTIAL LOG |
| 7S 1E20B03 | 69 | 469 | | NO CONSTRUCTION DATA |
| 7S 1E21A02 | 59 | 200 | | |
| 7S 1E21E02 | 40 | 752 | 389-738 | |
| 7S 1E21E03 | 69 | 803 | 406-785 | |
| 7S 1E21E99 | 69 | | | NO CONSTRUCTION DATA |
| 7S 1E21K02 | 70 | 468 | 100-450 | |
| 7S 1E22H06 | 69- | 756 | 314-737 | |
| 7S 1E22K01 | 52 | 312 | | CONFIDENTIAL LOG |
| 7S 1E23B01 | 69 | | | NO CONSTRUCTION DATA |
| 7S 1E23D01 | 70 | 430 | 314-360 | |
| 7S 1E23E01 | 62 | 200 | 80-200 | |
| 7S 1E23F04 | 69 | 306 | | CONFIDENTIAL LOG |
| 7S 1E23K01 | 51-63 | 550 | | DESTROYED |
| 7S 1E24F02 | 69- | | | NO CONSTRUCTION DATA |
| 7S 1E25A02 | 54-72 | 350 | | DESTROYED |
| 7S 1E25E04 | 61 | 298 | 168-248 | |
| 7S 1E25M04 | 70 | 268 | | NO CONSTRUCTION DATA |
| 7S 1E26R01 | 51 | 264 | | NO CONSTRUCTION DATA |
| 7S 1E27F01 | 45 | | | NO CONSTRUCTION DATA |
| 7S 1E27G05 | 64 | 325 | | CONFIDENTIAL LOG |
| 7S 1E29A02 | 69- | 438 | 210-332 | |
| 7S 1E29J03 | 69 | | | NO CONSTRUCTION DATA |
| 7S 1E29Q01 | 48 | 280 | 75-280 | |
| 7S 1E30B04 | 52-71 | 217 | | DESTROYED |
| 7S 1E31A01 | 36 | 360 | | NO CONSTRUCTION DATA |
| 7S 1E32B01 | 70 | 250 | | NO CONSTRUCTION DATA |
| 7S 1E32G01 | 71 | 460 | 185-400 | |
| 7S 1E32J03 | 69 | 315 | | NO CONSTRUCTION DATA |
| 7S 1E32R02 | 69 | 350 | 135-300 | |
| 7S 1E33M03 | 57 | 116 | 45-110 | |
| 7S 1E33P04 | 53 | 250 | | NO CONSTRUCTION DATA |
| 7S 1E35E01 | 36 | 300 | | NO CONSTRUCTION DATA |
| 7S 1E35G01 | 36 | 450 | | NO CONSTRUCTION DATA |
| 7S 1E36G01 | 62 | | | NO CONSTRUCTION DATA |
| 7S 1E36L03 | 51- | | | NO CONSTRUCTION DATA |
| 7S 2E06N04 | 69 | 500 | 225-455 | |
| 7S 2E07B02 | 53 | 410 | | NO CONSTRUCTION DATA |
| 7S 2E07M01 | 57 | 525 | | NO CONSTRUCTION DATA |
| 7S 2E07Q01 | 59 | 500 | | NO CONSTRUCTION DATA |
| 7S 2E17D01 | 69 | 600 | 375-560 | |
| 7S 2E17G02 | 39 | 400 | | NO CONSTRUCTION DATA |
| 7S 2E17K02 | 70 | | | NO CONSTRUCTION DATA |
| 7S 2E17Q02 | 39 | 375 | | NO CONSTRUCTION DATA |
| 7S 2E17R04 | 70 | | | NO CONSTRUCTION DATA |
| 7S 2E18B02 | 69 | 520 | 203-280 | |
| 7S 2E18B05 | 57 | 242 | | NO CONSTRUCTION DATA |

TABLE 17 (CONTINUED)

NORTH SANTA CLARA WELL QUALIFICATION LISTING

| WELL LOCATION NUMBER | PERIOD OF RECORD | DEPTH IN FEET | PERFORATED INTERVAL IN FEET | REMARKS |
|---|---|---|---|---|
| 7S 2E19B02 | 53 | 215 | | NO CONSTRUCTION DATA |
| 7S 2E19E01 | 45 | 275 | | NO CONSTRUCTION DATA |
| 7S 2E19E02 | 71-72 | | | DESTROYED |
| 7S 2E19J01 | 53 | 275 | | NO CONSTRUCTION DATA |
| 7S 2E20C04 | 69 | 760 | 300-760 | |
| 7S 2E20E05 | 68 | 408 | 65-405 | |
| 7S 2E20H02 | 51 | 310 | | CONFIDENTIAL LOG |
| 7S 2E20R01 | 69 | 315 | 110-310 | |
| 7S 2E21G01 | 39 | 358 | 88-353 | |
| 7S 2E28F01 | 68 | | | NO CONSTRUCTION DATA |
| 7S 2E29B01 | 69 | | | NO CONSTRUCTION DATA |
| 7S 2E33C01 | 55 | 61 | | NO CONSTRUCTION DATA |
| 7S 2E33C03 | 69 | 370 | | NO CONSTRUCTION DATA |
| 7S 2E33C05 | 53 | 32 | | NO CONSTRUCTION DATA |
| 7S 1W01N02 | 62- | 604 | | CONFIDENTIAL LOG |
| 7S 1W02A01 | 60-62 | 600 | | CONFIDENTIAL LOG |
| 7S 1W02G01 | 36- | 320 | | NO CONSTRUCTION DATA |
| 7S 1W02G02 | 69 | 864 | 660-814 | |
| 7S 1W02G03 | 69 | 792 | 361-717 | |
| 7S 1W02P02 | 69 | 520 | | CONFIDENTIAL LOG |
| 7S 1W03H01 | 69 | 650 | | NO CONSTRUCTION DATA |
| 7S 1W03Q01 | 69 | 784 | 651-771 | |
| 7S 1W04D01 | 69 | 580 | | NO CONSTRUCTION DATA |
| 7S 1W04E02 | 69 | 570 | | CONFIDENTIAL LOG |
| 7S 1W04N01 | 69 | 600 | | CONFIDENTIAL LOG |
| 7S 1W04N02 | 50 | 594 | 310-563 | |
| 7S 1W04Q01 | 69 | 600 | 306-497 | |
| 7S 1W05P02 | 69 | 770 | | CONFIDENTIAL LOG |
| 7S 1W06D01 | 56 | 550 | 179-517 | |
| 7S 1W06P01 | 69 | 706 | | CONFIDENTIAL LOG |
| 7S 1W07K01 | 68 | 435 | 231-415 | |
| 7S 1W07N01 | 69 | 760 | | NO CONSTRUCTION DATA |
| 7S 1W08B02 | 69- | 800 | | NO CONSTRUCTION DATA |
| 7S 1W08N01 | 69 | 604 | 302-586 | |
| 7S 1W09E02 | 71 | | | NO CONSTRUCTION DATA |
| 7S 1W09G01 | 50 | 300 | | NO CONSTRUCTION DATA |
| 7S 1W09J01 | 69 | 500 | | CONFIDENTIAL LOG |
| 7S 1W09N02 | 69- | 815 | | CONFIDENTIAL LOG |
| 7S 1W09Q01 | 69 | 570 | | CONFIDENTIAL LOG |
| 7S 1W10D01 | 69 | 865 | | NO CONSTRUCTION DATA |
| 7S 1W11E01 | 40-62 | 236 | | DESTROYED |
| 7S 1W13E01 | 36 | 618 | 568-614 | |
| 7S 1W13J07 | 69 | 800 | | CONFIDENTIAL LOG |
| 7S 1W13K04 | 69 | 550 | 315-507 | |
| 7S 1W14B01 | 56 | 367 | 213-360 | |
| 7S 1W14N01 | 49-71 | 440 | | DESTROYED |
| 7S 1W15D01 | 69 | 660 | | CONFIDENTIAL LOG |
| 7S 1W15E01 | 69 | 490 | | CONFIDENTIAL LOG |
| 7S 1W17A01 | 69 | 666 | | CONFIDENTIAL LOG |

TABLE 17 (CONTINUED)

NORTH SANTA CLARA WELL QUALIFICATION LISTING

| WELL LOCATION NUMBER | PERIOD OF RECORD | DEPTH IN FEET | PERFORATED INTERVAL IN FEET | REMARKS |
|---|---|---|---|---|
| 7S 1W17E01 | 69 | 599 | | NO CONSTRUCTION DATA |
| 7S 1W17P01 | 69- | 716 | 321-712 | |
| 7S 1W18K01 | 69 | 820 | 310-800 | |
| 7S 1W18R01 | 69- | 612 | | NO CONSTRUCTION DATA |
| 7S 1W20L02 | 69 | 850 | 360-834 | |
| 7S 1W20L03 | 69 | 913 | 400-890 | |
| 7S 1W21A01 | 69 | 500 | | NO CONSTRUCTION DATA |
| 7S 1W21N99 | 39-67 | 607 | | DESTROYED |
| 7S 1W21P01 | 65-71 | 360 | | DESTROYED |
| 7S 1W22E02 | 61 | 568 | 301-552 | |
| 7S 1W22E06 | 69 | 750 | 308-712 | |
| 7S 1W22E09 | 69 | 800 | 360-775 | |
| 7S 1W22E14 | 69 | 800 | 334-786 | |
| 7S 1W24A01 | 69 | 202 | 132-196 | |
| 7S 1W24E02 | 71- | | | NO CONSTRUCTION DATA |
| 7S 1W24H02 | 61 | 360 | | NO CONSTRUCTION DATA |
| 7S 1W24J03 | 61-62 | 838 | 336-822 | |
| 7S 1W24N01 | 71-71 | | | DESTROYED |
| 7S 1W25C01 | 67- | 400 | | NO CONSTRUCTION DATA |
| 7S 1W25L01 | 36 | 404 | | NO CONSTRUCTION DATA |
| 7S 1W26E01 | 61-62 | 536 | | CONFIDENTIAL LOG |
| 7S 1W26Q10 | 70 | | | NO CONSTRUCTION DATA |
| 7S 1W26R02 | 69-74 | 915 | | CONFIDENTIAL LOG |
| 7S 1W27E02 | 69-71 | 600 | | DESTROYED |
| 7S 1W27G01 | 69 | 685 | | NO CONSTRUCTION DATA |
| 7S 1W30E03 | 59 | 450 | | CONFIDENTIAL LOG |
| 7S 1W31H03 | 36-71 | 400 | | DESTROYED |
| 7S 1W31J02 | 69 | 880 | 304-858 | |
| 7S 1W32A01 | 68 | | | NO CONSTRUCTION DATA |
| 7S 1W33K01 | 69 | 607 | | CONFIDENTIAL LOG |
| 7S 1W33M02 | 69 | 747 | | NO CONSTRUCTION DATA |
| 7S 1W34F01 | 69 | 810 | 360-785 | |
| 7S 1W34F02 | 69 | 846 | 370-828 | |
| 7S 1W35H01 | 57- | 390 | | NO CONSTRUCTION DATA |
| 7S 1W36B01 | 69 | 500 | | NO CONSTRUCTION DATA |
| 7S 2W01B01 | 69 | 615 | | NO CONSTRUCTION DATA |
| 7S 2W01E02 | 69 | 845 | 300-820 | |
| 7S 2W01H01 | 69 | 708 | | NO CONSTRUCTION DATA |
| 7S 2W02E04 | 70-71 | | | DESTROYED |
| 7S 2W02G01 | 69 | 690 | | CONFIDENTIAL LOG |
| 7S 2W02K02 | 69 | 640 | | CONFIDENTIAL LOG |
| 7S 2W03A02 | 69 | 692 | 345-672 | |
| 7S 2W03C02 | 69 | 639 | | NO CONSTRUCTION DATA |
| 7S 2W03D01 | 69 | 498 | | NO CONSTRUCTION DATA |
| 7S 2W03D02 | 69- | 640 | | CONFIDENTIAL LOG |
| 7S 2W03H01 | 69 | 630 | | CONFIDENTIAL LOG |
| 7S 2W03R01 | 52 | 520 | 303-514 | |
| 7S 2W04G01 | 31 | 450 | | NO CONSTRUCTION DATA |
| 7S 2W09A01 | 68 | 240 | | CONFIDENTIAL LOG |

NORTH SANTA CLARA WELL QUALIFICATION LISTING

| WELL LOCATION NUMBER | PERIOD OF RECORD | DEPTH IN FEET | PERFORATED INTERVAL IN FEET | REMARKS |
|---|---|---|---|---|
| 7S 2W13C01 | 69 | 715 | | CONFIDENTIAL LOG |
| 7S 2W14H02 | 66 | 470 | | NO CONSTRUCTION DATA |
| 7S 2W22A01 | 36- | 620 | | NO CONSTRUCTION DATA |
| 7S 2W23C01 | 40-71 | 300 | | DESTROYED |
| 7S 2W25M02 | 36 | 465 | | NO CONSTRUCTION DATA |
| 7S 2W36A01 | 67- | | | NO CONSTRUCTION DATA |
| 8S 2E06P02 | 36 | 200 | | NO CONSTRUCTION DATA |
| 8S 2E07A03 | 36 | 203 | | NO CONSTRUCTION DATA |
| 8S 2E07F01 | 59 | 300 | | CONFIDENTIAL LOG |
| 8S 2E08K99 | 52- | 300 | | NO CONSTRUCTION DATA |
| 8S 2E16E98 | 36 | 91 | | |
| 8S 2E16N01 | 69- | | | NO CONSTRUCTION DATA |
| 8S 2E17L01 | 52 | 60 | | NO CONSTRUCTION DATA |
| 8S 2E17N01 | 53 | 106 | | NO CONSTRUCTION DATA |
| 8S 2E18E01 | 36 | 120 | | NO CONSTRUCTION DATA |
| 8S 2E18L01 | 36 | 290 | | NO CONSTRUCTION DATA |
| 8S 2E19A01 | 36- | 209 | | NO CONSTRUCTION DATA |
| 8S 2E20H02 | 70 | 225 | | NO CONSTRUCTION DATA |
| 8S 2E20F01 | 48 | 305 | | NO CONSTRUCTION DATA |
| 8S 2E22D01 | 36 | 86 | | NO CONSTRUCTION DATA |
| 8S 2E22F01 | 68 | | | NO CONSTRUCTION DATA |
| 8S 2E26M02 | 62 | 150 | | NO CONSTRUCTION DATA |
| 8S 2E27G01 | 68 | | | NO CONSTRUCTION DATA |
| 8S 2E28H02 | 68 | | | NO CONSTRUCTION DATA |
| 8S 2E31Q01 | 69 | 56 | | NO CONSTRUCTION DATA |
| 8S 2E34E01 | 68 | | | NO CONSTRUCTION DATA |
| 8S 2E35G01 | 69 | 150 | | NO CONSTRUCTION DATA |
| 8S 2E35M01 | 59 | 90 | | NO CONSTRUCTION DATA |
| 8S 1E01Q01 | 48 | 120 | | NO CONSTRUCTION DATA |
| 8S 1E02C02 | 62 | 165 | | NO CONSTRUCTION DATA |
| 8S 1E02H01 | 69 | 200 | | NO CONSTRUCTION DATA |
| 8S 1E02R01 | 70 | | | NO CONSTRUCTION DATA |
| 8S 1E03N01 | 69- | | | NO CONSTRUCTION DATA |
| 8S 1E04A05 | 62 | 200 | | NO CONSTRUCTION DATA |
| 8S 1E04P01 | 51- | 130 | | |
| 8S 1E04P98 | 62-71 | 235 | | DESTROYED |
| 8S 1E04Q05 | 71- | 224 | | CONFIDENTIAL LOG |
| 8S 1E05D01 | 68 | | | NO CONSTRUCTION DATA |
| 8S 1E05H06 | 69 | 440 | 82-340 | |
| 8S 1E05H07 | 69 | 440 | 100-415 | |
| 8S 1E05K02 | 62 | 320 | | NO CONSTRUCTION DATA |
| 8S 1E05N01 | 62 | 200 | | NO CONSTRUCTION DATA |
| 8S 1E07A01 | 71-71 | | | DESTROYED |
| 8S 1E07D01 | 45 | 327 | | NO CONSTRUCTION DATA |
| 8S 1E07G02 | 71 | | | NO CONSTRUCTION DATA |
| 8S 1E07J01 | 50 | 200 | | NO CONSTRUCTION DATA |
| 8S 1E08G02 | 70- | | | NO CONSTRUCTION DATA |
| 8S 1E08H01 | 67- | 220 | | NO CONSTRUCTION DATA |
| 8S 1E08P03 | 71 | 275 | | NO CONSTRUCTION DATA |

TABLE 17 (CONTINUED)

NORTH SANTA CLARA WELL QUALIFICATION LISTING

| WELL LOCATION NUMBER | PERIOD OF RECORD | DEPTH IN FEET | PERFORATED INTERVAL IN FEET | REMARKS |
|---|---|---|---|---|
| 8S 1E08R01 | 62- | 255 | 40-180 | |
| 8S 1E09H01 | 50 | 298 | | NO CONSTRUCTION DATA |
| 8S 1E09L03 | 48 | 50 | | NO CONSTRUCTION DATA |
| 8S 1E09M03 | 71 | | | NO CONSTRUCTION DATA |
| 8S 1E10D06 | 62 | 285 | | NO CONSTRUCTION DATA |
| 8S 1E10G02 | 69 | 372 | 87-186 | |
| 8S 1E10J01 | 38 | | | |
| 8S 1E10K03 | 69 | 382 | 56-252 | |
| 8S 1E10K04 | 69 | 226 | 84-200 | |
| 8S 1E10L04 | 36 | | | NO CONSTRUCTION DATA |
| 8S 1E11N01 | 59 | 86 | | NO CONSTRUCTION DATA |
| 8S 1E11Q01 | 69 | 160 | | NO CONSTRUCTION DATA |
| 8S 1E12C01 | 63 | 250 | | NO CONSTRUCTION DATA |
| 8S 1E12G02 | 59-72 | 220 | | NO CONSTRUCTION DATA |
| 8S 1E13H03 | 36- | | | NO CONSTRUCTION DATA |
| 8S 1E13J02 | 71- | | | DESTROYED |
| 8S 1E14R01 | 62-69 | 168 | | CONFIDENTIAL LOG |
| 8S 1E14D02 | 70 | | | NO CONSTRUCTION DATA |
| 8S 1E14D04 | 71- | 108 | | DESTROYED |
| 8S 1E15C02 | 64- | 148 | | NO CONSTRUCTION DATA |
| 8S 1E15E02 | 62 | 148 | | NO CONSTRUCTION DATA |
| 8S 1E16N07 | 70 | 36 | | NO CONSTRUCTION DATA |
| 8S 1E17A01 | 36 | 165 | | NO CONSTRUCTION DATA |
| 8S 1E17D01 | 69 | 480 | | NO CONSTRUCTION DATA |
| 8S 1E17R02 | 61 | 125 | | NO CONSTRUCTION DATA |
| 8S 1E20Q01 | 62 | 38 | | NO CONSTRUCTION DATA |
| 8S 1E27C02 | 62- | 70 | | NO CONSTRUCTION DATA |
| 8S 1E27C99 | 66-69 | 36 | | DESTROYED |
| 8S 1W03H01 | 69-71 | 700 | | DESTROYED |
| 8S 1W03K01 | 69 | 246 | | NO CONSTRUCTION DATA |
| 8S 1W03K03 | 63 | 94 | | NO CONSTRUCTION DATA |
| 8S 1W04K01 | 70 | 600 | | NO CONSTRUCTION DATA |
| 8S 1W05A01 | 56 | 230 | | NO CONSTRUCTION DATA |
| 8S 1W05K04 | 68- | | | NO CONSTRUCTION DATA |
| 8S 1W08J05 | 68- | 150 | | NO CONSTRUCTION DATA |
| 8S 1W10F02 | 00-74 | 458 | | CONFIDENTIAL LOG |
| 8S 1W11R01 | 36- | 384 | | NO CONSTRUCTION DATA |
| 8S 1W12Q02 | 62 | 200 | | NO CONSTRUCTION DATA |
| 8S 1W15C01 | 68 | | | NO CONSTRUCTION DATA |
| 8S 2W01C01 | | 500 | | NO CONSTRUCTION DATA |

4. Fairly long period of record of measurements. Although not as essential as first three criteria, a well with a historic water level record is preferable to a new well.

With the above data available, personnel with an understanding of the subsurface conditions (preferably a Certified Engineering Geologist) can certify that water level measurements from a particular well reflect the potentiometric surface of a specific aquifer, or group of aquifers. When this is done, fluctuations of the water levels in the particular well become meaningful data.

Qualified monitoring wells should be identified through the use of information on the buried stream channels contained on Figure 5. Thus, the ideal monitoring net will contain not only those representative wells that tap principal ground water conduits, but additional wells reflecting effects of the principal faults.

## Proposed Network

Proposed new network of monitoring wells was developed from examination of the detailed buried-channel maps which were discussed in Chapter III. Examination of these maps indicated that there were discreet areas where certain buried channels overlay each other. This afforded the identification of areas where monitoring wells could be located so as to reflect water levels for a given zone.

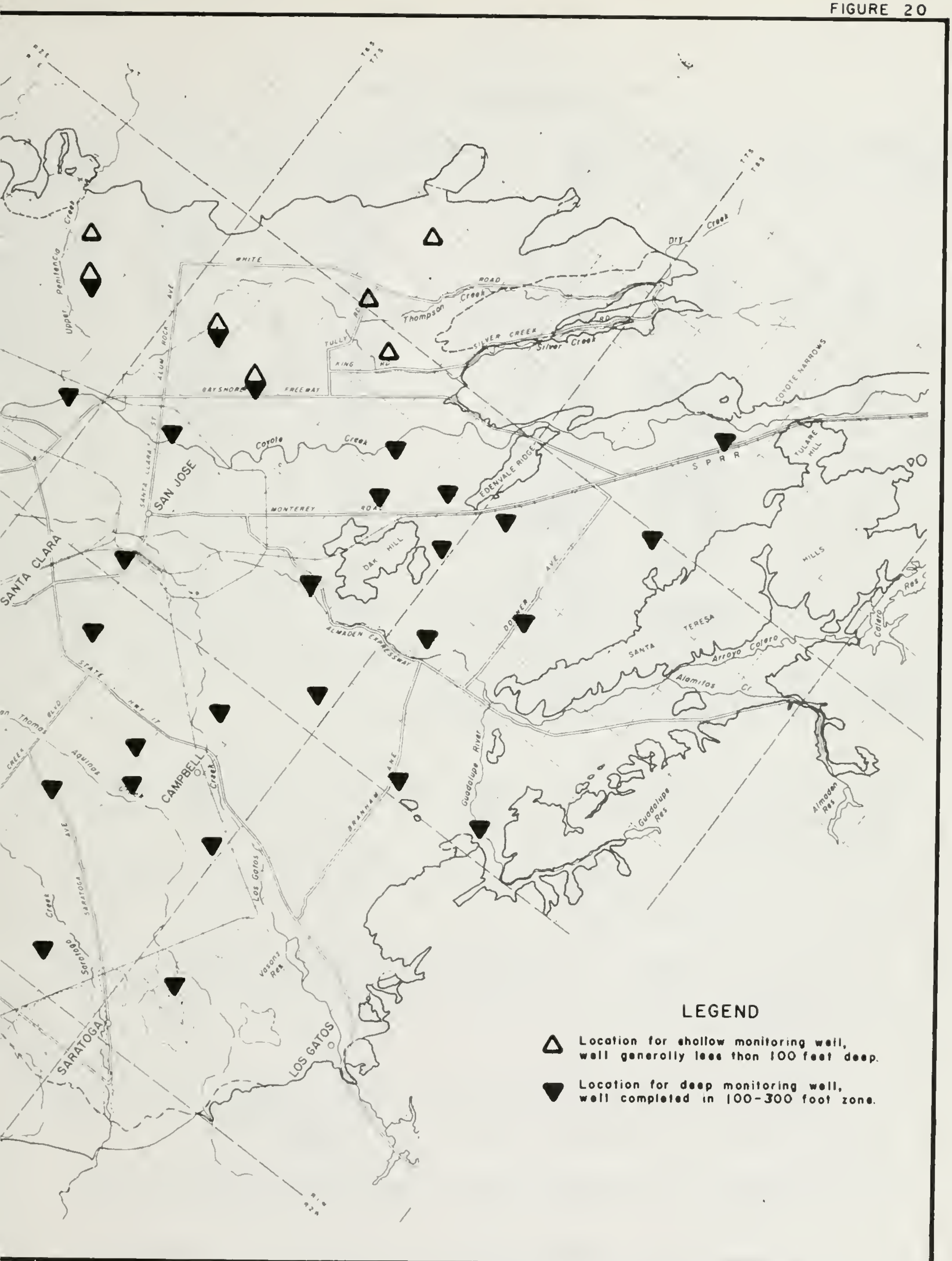
Evaluation of the geohydrology of the area revealed that the bayward portion of the valley (north of Bayshore Freeway and west of Nimitz Freeway) contains an upper, or essentially unconfined, ground water zone and a lower, or confined, ground water zone. These two zones are separated by a relatively impermeable clay layer. Upgradient from these two zones is a relatively broad forebay that, for modelling purposes, is considered to be essentially unconfined. Thus, there are three types of monitoring wells that are recommended. The first are the shallow wells, those ranging to depths of about 400 feet (120 meters) in the forebay zone and to depths of about 150 feet (45 meters) in the bayward zone. The second are the deeper wells; these range to depths of about 600 feet (180 meters) in both zones. To reflect the deeper, or confined zones, these deeper wells must be perforated only in the lower interval. Finally, there are the composite wells. These normally will be gravel-envelope wells (as opposed to selective-perforation wells) and will tap all zones down to a depth of about 600 feet (180 meters).

In all, locations for 34 shallow wells, 8 deep wells, and 5 composite wells have been selected as a minimum network. Table 18 presents location and completion interval data for proposed monitoring wells; Figure 20 shows the areal distribution of the proposed monitoring well network.

## Implementation of Network

There are several steps that should be taken in establishing the new network:


PROPOSED MONITORING




# WELL NETWORK

## Table 18

### PROPOSED GROUND WATER SURVEILLANCE NETWORK FOR UPPER AQUIFERS

| Well Location | | | Well | Monitoring Elevation | |
|---|---|---|---|---|---|
| Twp. | Rge. | Sec. | Type[1/] | (feet) | (meters) |
| 5S | 1E | 31L | S | +10 to -80 | +3 to -24 |
| 5S | 3W | 35P | C | +30 to -250 | +9 to -76 |
| 6S | 1E | 7Q | S | +10 to -80 | +3 to -24 |
| | | 8Q | S | 70 to -30 | +21 to -9 |
| | | 9F | S | +120 to +10 | +36 to +3 |
| | | 20B | S | +80 to -35 | +24 to -11 |
| | | 26D | S | +210 to +120 | +64 to +37 |
| | | 27L | C | +130 to -180 | +39 to -55 |
| | | 32J | D | -75 to -225 | -23 to -69 |
| 6S | 1W | 10R | C | -10 to -295 | -3 to -90 |
| | | 12Q | C | 0 to -285 | 0 to -87 |
| | | 20Q | C | +5 to -275 | +1 to -84 |
| | | 23M | C | 0 to -285 | 0 to -87 |
| | | 24R | C | +10 to -270 | +3 to -82 |
| | | 35R | C | +140 to -140 | +43 to -43 |
| 6S | 2W | 9H | C | -15 to -295 | -5 to -90 |
| | | 22P | C | +70 to -210 | +21 to -64 |
| | | 24L | C | +30 to -250 | +9 to -76 |
| | | 29L | D | +70 to -130 | +21 to -40 |
| | | 33H | D | +50 to -150 | +15 to -46 |
| | | 36L | D | +40 to -160 | +12 to -49 |
| 6S | 3W | 3N | D | 0 to -200 | 0 to -61 |
| | | 13A | D | -50 to -250 | -15 to -76 |
| 7S | 2E | 17K | S | +340 to +260 | +103 to +79 |
| | | 18E | S | +120 to +40 | +36 to +12 |
| 7S | 1E | 2N | C | +85 to -195 | +26 to -59 |
| | | 7P | D | -10 to -210 | -3 to -64 |
| 7S | 1E | 9C | D | -5 to -205 | -2 to -62 |
| | | 10R | C | +90 to -190 | +27 to -58 |
| | | 24B | S | +125 to +45 | +38 to +14 |
| | | 26C | D | +50 to -150 | +15 to -48 |
| | | 27K | D | +45 to -155 | +14 to -47 |
| | | 29H | D | +30 to -170 | +12 to -52 |
| | | 31K | D | +60 to -140 | +18 to -43 |
| | | 34Q | D | +55 to -145 | +17 to -44 |
| | | 35F | D | +65 to -135 | +20 to -41 |
| 7S | 1W | 3F | C | +50 to -230 | +15 to -70 |
| | | 5K | D | 0 to -200 | 0 to -61 |
| | | 13D | D | +10 to -190 | +3 to -58 |
| | | 18C | D | +80 to -120 | +24 to -37 |
| | | 21B | D | +55 to -145 | +17 to -44 |
| | | 23N | D | +70 to -130 | +21 to -40 |
| | | 25L | D | +70 to -130 | +21 to -40 |
| | | 27B | D | +70 to -130 | +21 to -40 |
| | | 30K | D | +175 to -25 | +53 to -8 |
| | | 34Q | D | +120 to -80 | +37 to -24 |
| 7S | 2W | 2G | D | +80 to -120 | +24 to -37 |
| | | 13P | D | +150 to -50 | +46 to -15 |
| 8S | 2E | 17H | D | +120 to -80 | +37 to -24 |
| 8S | 1E | 2G | D | +70 to -130 | +21 to -40 |
| | | 4F | D | +65 to -135 | +20 to -41 |
| | | 7L | D | +125 to -75 | +38 to -23 |
| | | 10L | D | +75 to -125 | +23 to -38 |
| | | 13H | D | +80 to -120 | +24 to -37 |
| | | 19C | D | +180 to -20 | +55 to -6 |
| 8S | 1W | 5L | D | +210 to +10 | +64 to +3 |

1/ S - Shallow well: Completed in depth interval from 20 to 100 feet *(6 to 30 m)*.
D - Deep well: Completed in depth interval from 100 to 300 feet *(30 to 90 m)*.
C - Composite well: Contains two piezometers; one each completed in shallow and deep zones.

1. Search records and make a field canvas to locate all wells and data on wells in the vicinity of a proposed monitoring well locations.

2. Determine if an existing well can be used or modified for use as a monitoring well.

3. If Step 2 is negative, or cost is excessive, drill and install a monitoring well. In some areas, a single drill hole may be designed to contain several piezometers, each monitoring a different depth.

4. Monitoring wells should be located beyond the local influence of large municipal and industrial wells. Conversely, consideration should be given to restricting the placement of such new wells that would adversely affect monitoring wells.

5. The continuity of existing water level measurements should not be broken until there is some overlap of record.

Many of the water level measurements now available are measurements taken by the agency that operates the well. Such measurements will probably be continued by such agencies for their own operating reasons.

# APPENDIX A

# GEOLOGY

(Published separately, August 1967)

APPENDIX B

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# APPENDIX C

## ENGLISH - METRIC EQUIVALENTS

Each unit with its abbreviation is followed by its equivalent in one or other units of the same quantity. In the text, the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

| | |
|---|---|
| Length | Inch (in) - 2.54 centimeter (cm)<br>Centimeter (cm) - 0.3937 inch (in)<br>Millimeter (mm) - 0.1 centimeter (cm); 0.039 inch (in)<br>Foot (ft) - 0.3048 meter (m)<br>Meter (m) - 3.2808 feet (ft); 39.37 inches (in)<br>Mile (mi) - 1.6094 kilometer (km)<br>Kilometer (km) - 0.6214 mile (mi) |
| Area | Acre (a) - 43,560 square feet ($ft^2$); 0.4047 hectare (ha)<br>Hectare (ha) - 10,000 square meters ($m^2$); 2.471 acres (a)<br>Square mile ($mi^2$) - 640 acres (a); 259 hectares (ha); 2.59 square kilometers ($km^2$)<br>Square kilometer ($km^2$) - 100 hectares (ha); 0.384 square mile ($mi^2$) |
| Volume | Gallon (gal) - 3.7853 liters (l); 0.00378 cubic meter ($m^3$)<br>Liter (l) - 0.2642 gallon (gal); 1.057 quarts (qt)<br>Cubic meter ($m^3$) - 264.173 gallons (gal); 1,000 liters (l) |
| Discharge | Million gallons per day (MGD) - 3780 cubic meters per day ($m^3/d$)<br>1,000 cubic meters per day ($m^3/d$) - 0.26 million gallons per day (MGD) |
| Ground Water Storage | Acre-foot (ac-ft) - 1,233.5 cubic meters ($m^3$)<br>Thousand acre-feet (ac-ft) - 1,233,500 cubic meters ($m^3$); 1.23 cubic hectometers ($hm^3$)<br>Cubic hectometer ($hm^3$) - Million cubic meters ($m^3$); 810.71 acre-feet (ac-ft) |
| Percolation | Acre-foot per acre per day (ac-ft/ac/day) - 499.2 cubic meters per hectare per day ($m^3/ha/d$)<br>Cubic meter per hectare per day ($m^3/ha/d$) - 0.002 acre-foot per acre per day (ac-ft/ac/day) |
| Concentration | Milligram per liter (mg/l) - 1 part per million (ppm)<br>Microgram per liter (µg/l) - 0.001 milligram per liter (mg/l), 0.001 part per million (ppm) |
| Permeability | Gallon per day per square foot ($gal/day/ft^2$) - 0.055 darcys (D)<br>Darcy (D) - 18.2 gallons per day per square foot ($gal/day/ft^2$) |
| Transmissivity | Gallon per day per foot (gpd/ft) - 0.134 square feet per day ($ft^2/day$); 0.0124 square meters per day ($m^2/day$)<br>Square meter per day ($m^2/day$) - 10.76 square feet per day ($ft^2/day$); 80.5 gallons per day per foot (gpd/ft) |
| Capacity | Cubic inch per foot ($in^3/ft$) - 53.76 cubic centimeters per meter ($cm^3/m$)<br>Cubic centimeter per meter ($cm^3/m$) - 0.018 cubic inch per foot ($in^3/ft$) |